5 Series Firetube Boilers

Installation, Operation and Maintenance Manual

50-1000 Horse Power
Dry Back Horizontal Fire Tube Design
Preface

To: Owners, Operators and Maintenance Personnel

This operation and maintenance manual presents information to properly install, operate, and care for the York-Shipley Global Series 500C Boiler. Study its contents in its entirety. The York-Shipley Global Boiler will provide efficient, continued reliability, if properly operated and maintained. No attempt should be made to operate the boiler until a complete understanding of the principles of operation and all boiler components is thoroughly understood. Read and understand all labels applied to the boiler and boiler room equipment (See Section 1-6, "Warning and Caution Label Identification").

The York-Shipley Global Boiler is designed and constructed to give excellent service and long life. The equipment has been supplied with electrical and mechanical devices to provide for safe and efficient automatic operation but does not relieve any responsibility of operating and maintenance personnel.

It is solely the operator's responsibility to properly operate and maintain the boiler equipment. This manual, together with information provided by manufacturers of ancillary equipment, controls, components and fuel burning equipment, is intended to supplement operating and maintenance personnel’s knowledge and responsibility for proper care and operation.

Federal, State, Municipal, Insurance and Local Jurisdictions Having Authority mandate certain code compliance which require a variety of electrical and safety devices. Accordingly, installation requirements and devices may vary significantly from one boiler to another and may take precedence to the information. The York-Shipley Global Series 500C IO&M Manual is designed to supply information on standard York-Shipley Global boiler equipment.

York-Shipley Global strongly recommends that a boiler room record book, or log, be maintained to ensure that daily, weekly, monthly, and yearly maintenance activities be recorded. Any unusual occurrences should also be documented. A log will serve as an important guide to ascertain and investigate operational difficulties.

The main cause of damage to any boiler is low water operating conditions. York-Shipley Global cannot emphasize enough the importance of proper and sustained maintenance and testing.
practices of boiler low water cutoff controls. Periodic internal inspection, of these devices, must be made to prevent obstruction of device. Float Ball type low water cutoff controls must be frequently inspected to check for any interference that would impede movement of float mechanism and correct any abnormal condition.

Water side condition of the boiler is of extreme importance. The absence of water treatment, or improper water treatment, will result in serious damage to the boiler and/or related boiler room equipment, which is not covered by York-Shipley Global's Standard Limited Warranty, or any other warranty or guarantee. Waterside surfaces must be frequently inspected for the presence of mud, sludge, scale and corrosion. It is standard industrial practice to employ the services of a competent and qualified water quality treatment service provider, or water quality expert, to recommend proper and sustained water treatment maintenance program for specific water quality conditions in your local area.

York-Shipley Global, a Division of Power Mechanical, Inc. practices a continuing improvement program; therefore, the information contained in this manual on specific features is subject to change without notice.

DANGER - HAZARD OF ELECTRIC SHOCK

- Disconnect all power supplies before servicing equipment. Multiple power supplies are provided and each must be secured in the off position or physically disconnected. Reset buttons for electronic control and magnetic starter inside panel. Wire all circuits NEC. CLASS I. use copper conductors only.

- This equipment is not intended for use in furnishing temporary heat to the structure in which it is installed, prior to the completion and acceptance of such structure and installation by the owner or other persons for whom the entire project is being constructed. Therefore, the warranty and warranty service normally issued in respect to this equipment will not apply during periods of temporary heat nor to any defect in material and workmanship in the equipment becoming apparent after any improper use.

- This unit shall be installed on a non-combustible floor with the following clearances to combustible material as required by Underwriters Laboratories Inc.: from top of boiler 48”, from front of boiler 96”, from smoke pipe in any direction 36”, from back of boiler 36”, from
side of boiler 36” - the flue pipe shall not pass through any floor or ceiling or any combustible wall or partition unless suitably guarded. In every case, installations must comply with all applicable insurance requirements, codes and regulations of Jurisdiction Having Authority.

**CAUTION**

- This product may utilize combustible fuel(s) and may utilize, or generate, hot water and/or steam at elevated temperatures above atmospheric pressure (14.7 PSIA/101.32KPa). Installers and operators of this equipment, as well as maintenance personnel should be properly trained and are cautioned that improper or careless actions may result in a hazardous condition and/or personal injury.

- Equipment to be used only for designed use and within designed capacity limits.

- Never by-pass safety control devices.

- This product was designed and constructed under the requirements of ASME Boiler and Pressure Vessel Code and registered with the National Board of Boiler and Pressure Vessel Inspectors ("The National Board"). Documentation of this process has been provided with the product and should be permanently retained. To maintain the integrity of this equipment, all weld repairs must be accomplished only by authorized repair organizations and subsequently inspected and accepted by a National Board authorized inspection agency.

**WARNING- FOR YOUR PERSONAL SAFETY**

- Read and Understand all Instructions and Warnings [Including all applicable Material Safety Data Sheets - (MSDS) relevant examples of which are provided in Appendix C of this manual] before using any product;

- Ensure all equipment is subjected to Routine Maintenance and Inspection;

- Replace damaged, missing or worn parts;
• Some parts weigh more than 50 pounds and will require more than one person to assemble and move;

• Make sure all electrical connections are properly grounded and adequate for the electrical load;

• When performing maintenance including, but not limited to, cutting, grinding, welding or cleaning wear suitable personal protection safety equipment [eye, hearing, and respiratory protection safety equipment];

• Make sure that any material being unbolted or cut is secured and will not free-fall, possibly causing injury or damage;

• Keep hands and body parts from direct contact with hot surfaces;

**WARNING**

• Proper lock out/tag out procedures must be followed to insure against the unintentional release of stored energy.

• Confined space entry procedures must be strictly observed to prevent injury or death.

• Make sure footing and body position will not cause a loss of balance in the event of an unexpected occurrence;

• Never work near energized electrical “live” circuits.

• Consult the *Installation, Operation and Maintenance Manual* or York-Shipley Global on any questions relating to proper maintenance, installation or operation of this equipment.
CAUTION

POTENTIAL HEALTH RISKS ASSOCIATED WITH FAILURE TO UTILIZE SPECIAL PROTECTION AND SPECIAL PRECAUTIONS ASSOCIATED WITH HAZARDOUS MATERIALS

The manufactures of the refractory and gaskets, as well as other materials commonly used in boilers have issued Materials Safety Data Sheets (MSDS's) for each of their products. Many of these products contain free or crystalline silica and other products which are considered hazardous and pose a health or safety risk if handled improperly. Crystalline silica has been classified as a Class 2A Carcinogen. Many other materials including fiberglass and the by-products of metal working, also pose potential health threats under various conditions. Typical Data Sheets for materials commonly used in boilers are included in Appendix C hereto and should be thoroughly reviewed prior to the cleaning, repair, maintenance or operation of boiler room equipment. These Data Sheets present detailed warnings on the hazards from materials used in the manufacture of boilers. They also present recommendations on the special precautions required to avoid health and safety risks.

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Section I
Introduction & General Description

1-1. Purpose

This technical manual provides the necessary information to install, start-up, operate, service, store and maintain the York-Shipley Global Series 500C Packaged Firetube Boilers manufactured by Power Mechanical, Inc. Throughout this manual the York-Shipley Global Series 500L Boiler will be referred to as the Series 500C Boiler, the packaged boiler, or more simply the boiler.

1-2. Arrangement

This technical manual comprises seven sections, arranged as follows:

Section I - Introduction and General Description states the purpose of this manual, the arrangement and content of the sections in the manual and briefly describes the physical and functional aspects of the Series 500C Boiler with some of the information presented in tabular format.

Section II - Storage provides information regarding care and maintenance prior to the unit being installed, boiler lay-up, dry storage and wet storage.

Section III - Installation and Arrangement describes the boiler room, sizes and arrangements, preliminary checks and inspection, placing the unit and preparing the system.

Section IV - Principles Of Operation and Safety provides a functional description of the system during various modes of operation. Safety precautions associated with the operation and/or maintenance of the boiler, burner and components are also specified in this section.

Section V - Start-Up, Adjustment and Operating Procedures details the function of all boiler operator controls and indicators and provides instructions for operating the boiler.
Section VI - Service and Maintenance provides preventative and corrective maintenance procedures for the Series 500C Boiler that includes inspection, troubleshooting performance verification and repair.

1-3. General Description

The information in this manual is directly applicable to the York-Shipley Global Series 500L Boiler.

1-4. The Boiler

The York-Shipley Global packaged boiler is a steam generating unit that can use a variety of fuels for generating heat to produce steam or hot water for industrial use. The boilers are self-contained units that range in size from 20 HP to 1000 HP. The boiler produces saturated steam which can be delivered at a variety of pressures as required by the end-user.

The packaged firetube boiler is so named because of the location of the combustion gases being inside the firing and convective tubes located in the boiler shell. The water converted into steam is located outside the tubes and inside the shell.

The firetube boiler relies on the large surface area of the tubes to transfer the heat generated by the combustion gases to the water. Firetube boilers in use today are classified as multiple-pass units with horizontal tubes employing forced draft gas flow.

The York-Shipley Global Series 500C boiler is manufactured by Power Mechanical, Inc., under the York-Shipley Global brand name.

The York-Shipley Global Series 500C boiler is a 3-pass water backed design, with two tube passes and one firing tube ("furnace") pass. Combustion is completed in the firing tube. Air is furnished by a forced draft blower to the burner where it is mixed with the selected fuel and introduced to the firing tube where they combust. The forced draft blower and the combustion process pushes the combustion gases through the three boiler passes to the flue gas vent at the rear of the boiler.
All packaged boilers are heat exchangers. The firetube boiler closely resembles a shell and tube type heat exchanger in construction. The major parts of the boiler are the shell, the firing and convective tubes, tube sheets, turning box areas, the burner and various controls. The shell is the largest component of the boiler. The shell is a pressure vessel which contains the steam and/or hot water. All of the other components attach to the shell which contains the firing and convective tubes. The shell has tube sheets at each end which holds the firing tube and convective tubes. The turning box areas are located outside the tube sheet on both ends. The burner supplies the fuel and combustion air to the firing tube in a state that is prepared to combust and begin the generation of steam or hot water.

1-5. Description of Boiler Components

Proper operation of the boiler requires that the operator understand the interface and operation of each of the components. Efficient control of the boiler is only possible when the operator understands the function and operation of each of the major components of the boiler systems.

Many of these components are purchased by York-Shipley Global from manufactures specializing in boiler controls and boiler related components. The individual manufacturer's operation and maintenance manuals have been furnished with your equipment. Reference is made to such operation and maintenance manuals for a full description of the function, operation, maintenance, and related warnings relative to each component.

Table 1-2. List of Firetube Boiler Basic Components

<table>
<thead>
<tr>
<th>No.</th>
<th>COMPONENT</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Air Compressor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Air Filter</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The air compressor air filter ensures a supply of clean air to the air compressor utilized in some instances for atomizing fuel oils.</td>
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</tr>
<tr>
<td>2</td>
<td>Blower Air Switch</td>
<td>The Blower Air Switch is actuated by the air pressure developed by the fan or forced draft blower and is connected in the running interlock circuit. Its contacts must be closed for the fuel valve to open.</td>
</tr>
<tr>
<td>3</td>
<td>Air Compressor Oil Reservoir</td>
<td>The Air Compressor Oil Reservoir ensures the delivery of clean lubricating oil to the air compressor. It is normally located at the top of the intake side of the air compressor.</td>
</tr>
<tr>
<td>4</td>
<td>Auxiliary Switch (Low Fire End Switch)</td>
<td>The Auxiliary Switch (Low Fire End Switch) is actuated by the modulating motor. It provides additional safety and prevents the burner from being ignited unless the modulating motor, forced draft damper and fuel valves are in low fire positions.</td>
</tr>
<tr>
<td>5</td>
<td>Return Oil Metering Valve</td>
<td>The Return Oil Metering Valve is adjusted to establish the proper oil pressure at the Metering Valve. The fuel oil pressure is read using a pressure gauge. The Return Oil Metering Valve is driven and controlled by the Modulating Motor through linkages.</td>
</tr>
<tr>
<td>6</td>
<td>Boiler Stamping</td>
<td>The ASME-National Board of Boiler and Pressure Vessel Inspectors Stamping should be copied by pencil rubbing and retained. It must be accessible for inspection purposes. Place the rubbing in Appendix E.</td>
</tr>
<tr>
<td>7</td>
<td>Burner ON/OFF Switch</td>
<td>The Burner On/Off Switch is used for manually starting and stopping burner operation. It is normally located at the control panel.</td>
</tr>
</tbody>
</table>
Table 1-2. List of Basic Firetube Boiler Components

<table>
<thead>
<tr>
<th>No.</th>
<th>COMPONENT</th>
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</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Gas Flow Control Valve</td>
<td>The Gas Flow Control Valve regulates the flow rate of natural gas to the burner. The power output of the boiler is controlled in this fashion. The Gas Flow Control Valve position is controlled by a Modulating Motor and operates in conjunction with the forced draft damper to control the combustion rate in the boiler.</td>
</tr>
<tr>
<td>9</td>
<td>Modulating Motor</td>
<td>The Modulating Motor operates both the Forced Draft Damper and the fuel valves through a linkage system. Typically, the flows of individual fuels may be controlled using adjustable cams.</td>
</tr>
<tr>
<td>10</td>
<td>Feedwater Control Valve (Optional)</td>
<td>The optional Feedwater Control Valve regulates the supply of boiler feedwater to the package boiler. The Feedwater Control Valve receives a control signal from the pump control and low water cutoff to control the water level in the boiler under varying load conditions.</td>
</tr>
<tr>
<td>11</td>
<td>Firetubes</td>
<td>The Firetubes contain and direct the combustion gases inside the boiler.</td>
</tr>
<tr>
<td>12</td>
<td>Forced Draft Damper</td>
<td>The Forced Draft Damper controls the flow of combustion air to/from the Forced Draft Fan or Blower. The damper position varies with the boiler load.</td>
</tr>
<tr>
<td></td>
<td><strong>Forced Draft Fan or Blower</strong></td>
<td>The Forced Draft Fan or Blower provides the combustion air to the burner assembly. The Forced Draft Fan or Blower operates continuously during boiler operation supplying combustion air. The Forced Draft Fan or Blower starts before the burner begins operation to prepare the boiler and firetube for combustion. The Forced Draft Fan or Blower stops after the boiler is purged of combustion gases. There is a delay sequence after burner shut down.</td>
</tr>
<tr>
<td>---</td>
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<td>---</td>
</tr>
<tr>
<td>14</td>
<td><strong>Gas Pressure Regulator (Optional)</strong></td>
<td>The optional Gas Pressure Regulator reduces the incoming fuel gas pressure to the proper level for burner operation. Refer to the gas line pressure on the factory test report inside the boiler control panel for factory recommended settings. The Gas Pressure Regulator operates independently of operator actions. Only the initial pressure setting is required to be set by the operator at initial startup.</td>
</tr>
<tr>
<td>15</td>
<td><strong>Ignition System Porcelain Insulator(s)</strong></td>
<td>These Porcelain Insulators insure a safe means of insulating the high voltage used by the ignition electrodes from the surrounding metal surfaces.</td>
</tr>
</tbody>
</table>
Table 1-2. List of Basic Firetube Boiler Components

<table>
<thead>
<tr>
<th>No.</th>
<th>COMPONENT</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Ignition System Transformer</td>
<td>The Ignition System Transformer steps up the voltage to supply the high voltage necessary for spark ignition. Should the gas main pressure change dramatically the operator may need to adjust the gas pressure regulator.</td>
</tr>
<tr>
<td>17</td>
<td>Main Fuel Valve</td>
<td>The boiler is equipped with one or more motor operated or solenoid valves in the gas or oil fuel supply lines. These valves provide a positive shut off of the fuel supplies to the burner.</td>
</tr>
<tr>
<td>18</td>
<td>Main Gas Shutoff Cock</td>
<td>The Main Gas Shutoff Cock is a hand operated device for opening and closing the main gas supply line to the burner.</td>
</tr>
<tr>
<td>19</td>
<td>Manual Potentiometer (Optional)</td>
<td>With the selector switch set to Manual, the optional Manual Potentiometer controls the positioning of the modulating motor, thus putting the firing rate directly under the control of the operator.</td>
</tr>
<tr>
<td>20</td>
<td>Modulating Pressure (or Temperature) Control Optional</td>
<td>The Modulating Pressure (or Temperature) Control sends a control signal to the modulating motor to control the firing rate to meet varying load demands.</td>
</tr>
<tr>
<td>21</td>
<td>Nozzle Air Pressure Gauge</td>
<td>The Nozzle Air Pressure Gauge indicates atomizing air pressure at the burner.</td>
</tr>
</tbody>
</table>
## SECTION I - GENERAL DESCRIPTION

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>Oil Metering Valve</td>
<td>The Oil Metering Valve controls the rate of flow of fuel oil to the burner nozzle.</td>
</tr>
<tr>
<td>23</td>
<td>Pilot Solenoid Valve</td>
<td>The Pilot Solenoid Valve is the normally closed valve in the line supplying fuel to the pilot. This valve is opened only during the period of ignition by the flame safeguard system.</td>
</tr>
<tr>
<td>24</td>
<td>Air Compressor Pump</td>
<td>The Air Compressor Pump furnishes filtered air used for atomizing the fuel oil at the burner nozzle.</td>
</tr>
<tr>
<td>25</td>
<td>Flame Safeguard Control</td>
<td>The Flame Safeguard Control establishes a control sequence for burner operation the control maintains a fixed, pre-assigned time schedule for each phase of burner operation. The timing is factory set by the manufacturer of the control and is not field adjustable. A scanner connected to verify the flame safeguard control responds to cause immediate shutoff of all fuel upon flame failure. The Flame Safeguard Control includes a safe-start feature, which prevents any unsafe operating condition. Any tampering with the Flame Safeguard Control System poses extreme risk to the boiler and personnel adjacent to the boiler.</td>
</tr>
</tbody>
</table>
Table 1-2. List of Firetube Boiler Basic Components

<table>
<thead>
<tr>
<th>No.</th>
<th>COMPONENT</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Pump Control and Low Water Cutoff</td>
<td>The Pump Control and Low Water Cutoff responds to the level of boiler water. Typically, this control is float operated. It performs two distinct functions: The first is to stop the firing of the boiler when the boiler water is below the safe operating level, the second is to control the feedwater flow rate to maintain the boiler water at the proper operating level. Any tampering with the Pump Control and Low Water Cutoff poses extreme risk to the boiler and personnel adjacent to the boiler. Be sure to follow the manufacturers maintenance requirements.</td>
</tr>
<tr>
<td>27</td>
<td>Pressure Relief Safety Valve</td>
<td>The Pressure Relief Safety Valve provides over pressure protection for the boiler shell. The safety valves are not actively controlled by the operator. The valves are preset and remain in service continuously. The valves relieve to atmosphere when over pressure conditions occur inside the shell of the boiler and reset when the condition is clear. The relief pressure is set by the spring pressure on the valve disc. Be sure to follow the manufacturers maintenance requirements.</td>
</tr>
<tr>
<td>28</td>
<td>Scanner</td>
<td>The Scanner verifies the presence of the flame and electronically alerts the Flame Safeguard Control to provide fuel cutoff in the event of flame failure.</td>
</tr>
<tr>
<td>Section</td>
<td>Component</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
<td>-------------</td>
</tr>
<tr>
<td>29</td>
<td>Steam Pressure or Pressure Temperature and Altitude Gauge</td>
<td>These gauges indicates internal boiler pressure or pressure-temperature conditions.</td>
</tr>
<tr>
<td>30</td>
<td>Test Tee</td>
<td>The Test Tee is located on the piping immediately below the boiler pressure gauge. On steam boilers it is supplied for the convenience of the boiler inspector in making routine checks of the calibration of the steam pressure gauge. It also serves to relieve the vacuum created by steam condensing upon shut down of the boiler. During normal boiler operation it remains closed.</td>
</tr>
<tr>
<td>31</td>
<td>Turning Boxes</td>
<td>The turning boxes direct the hot gases exiting the firing tube in the boiler into the second pass firetubes and from the second pass firetubes to the third pass firetubes.</td>
</tr>
<tr>
<td>32</td>
<td>Water Column Fittings</td>
<td>This assembly includes the Water Gauge Glass, Gauge Glass Shutoff Cocks and Water Column Trycocks.</td>
</tr>
</tbody>
</table>
1-6. Warning and Caution Label Identification

Read and understand each label placed on the boiler and boiler room equipment.

1-7. DEFINITION OF DANGER, WARNING AND CAUTION

DANGER used to indicate the presence of a hazard which will cause severe personal injury, death, or substantial property damage if the warning is ignored.

WARNING used to indicate the presence of a hazard which can cause severe personal injury, death, or substantial property damage if the warning is ignored.

CAUTION used to indicate the presence of a hazard which will or can cause minor personal injury or property damage if the warning is ignored.

Label 1.
Label 2.

### ASME Section IV

<table>
<thead>
<tr>
<th>Description</th>
<th>Units</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASME Sec IV</td>
<td></td>
<td>Construction of steam and hot water boilers.</td>
</tr>
<tr>
<td>MAX Firing Rate</td>
<td>GPH</td>
<td></td>
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<tr>
<td>MIN Firing Rate</td>
<td>CFH</td>
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<tr>
<td>LB/HR</td>
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<tr>
<td>MBH</td>
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<tr>
<td>BTU/GAL</td>
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<tr>
<td>BTU/CF</td>
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<td>CS</td>
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<tr>
<td>OIL</td>
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<tr>
<td>GAS</td>
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</tr>
</tbody>
</table>

- **Asme Section IV** constructed steam and hot water boilers, and **asme section I** constructed boilers equipped to operate at no more than 50 psig shall be installed with minimum clearances of 18 in at top, sides, and rear, 48 in from front, and 18 in from flue pipe.

- **Asme Section I** constructed boilers equipped to operate at over 50 psig shall be installed with minimum clearances of 48 in at top, 36 in at sides and rear, 96 in from front, and 36 in from flue pipe.

- Unit shall be operated and maintained only by competent and qualified operating, service and maintenance personnel. Consult manufacturer’s operation and maintenance manual.
Label 3. Typical Fuel Burning Equipment Electrical Data Tag

<table>
<thead>
<tr>
<th>Component Data</th>
<th>HP</th>
<th>Volts</th>
<th>Amps</th>
<th>Phase</th>
<th>Min Cir</th>
<th>Max Fuse</th>
<th>Ampacity</th>
<th>Amps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Blower Motor</td>
<td></td>
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<td>2. Fuel Pump Mtr</td>
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<td>3. Com'pr Motor</td>
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<tr>
<td>4. Elec Htr #1</td>
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<tr>
<td>5. Elec Htr #2</td>
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<td>6. Elec Htr #3</td>
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<td>7. Control Circuit</td>
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</tbody>
</table>

**ELECTRICAL DATA**

N-155124-A
Failure to adhere to the following Important Notes, Cautions, Warnings and Danger Notices may create a potential hazard resulting in serious and/or catastrophic Equipment, and/or process failure, property damage, personal injury and/or death.

**IMPORTANT NOTE**

To assure the proper and safe design, handling, storage, installation, commissioning, operation, and maintenance of this Equipment, it shall be necessary, and/or required to:

- Ensure installation, operation and maintenance compliance in accordance with the most current accepted editions of any and all applicable Codes and Standards, including, without limitation, those mandated by Local Utilities or Jurisdictions Having Authority (JHA).
- Employ and/or engage competent, qualified and, where mandated by Local Jurisdiction, Licensed Installation, Operating and/or Maintenance Personnel, including, without limitation, Mechanical, Heating, HVAC, Electrical, Control, Plumbing, Authorized Repair Contractors and Water Quality Service Providers, who are required engaged in such services, fully trained, and thoroughly familiar with applicable Codes, Standards and Regulations, system application, equipment, components and auxiliary support systems and have read, and thoroughly understand, the.Icon{
- Operating and Maintenance (O&M) Manual(s) and applicable Material Safety Data Sheets (MSDS), provided with Equipment, and cause to maintain a copy of O&M Manual(s), at or about the Equipment, for ready reference.

To assure Personnel Safety and Equipment useful life, it shall be necessary, and/or required to:

- Provide proper, and sustained, water quality maintenance program administered by competent and qualified Local Water Quality Service Provider, knowledgeable of system application, equipment, service and local environmental regulations, without limitation, governing the handling, storage and use of requisite chemicals utilized in prevention of scale formation, oxygen corrosion and pitting and to adequately ensure water quality to maintain equipment performance and useful life.
- Provide proper, and sustained, routine inspection and maintenance schedules and procedures.
- Replace damaged, corroded, missing and/or worn components and/or parts. Upon opening, replace any and all gasket materials.
- Maintain all Equipment components and auxiliary support system cover plates, enclosures and guards, service access ports, doors and inlet and discharge connections in place at all times during normal operation and stand-by mode, except as required to perform periodic inspections, service, maintenance and/or emergency procedures.
- Maintain suitable Personal Protection Safety Garments, Gear and Apparatus to adequately safeguard Personnel against injury, and/or harm, exposure, including, without limitation, headwear, full face attire, eyewear, ear plugs, gloves, steel reinforced footwear, respiratory设备, back support and above ground harness protection devices.
- Maintain suitable First Aid Stations, or kit, and ensure immediate Personnel access to fresh water and/or oxygen.
- Provide for adequate lighting, fresh water and outside air intake to Equipment environs.
- Equipment environs shall be kept clean, free and clear of any and all combustible materials and debris.
- Keep hands, and other extremities, from direct contact and exposure to surfaces at elevated temperatures, actuating, rotating or reciprocating components and energized electrical circuits.
- Ensure that Personnel holding, position and balance of or about Equipment. Always be aware of surroundings.
- Ensure additional Personnel is present during operation, service, maintenance and to aid in securing of, disconnect, removal and/or replacement of components which would require assistance, due to weight or physical dimension, possibly causing Personnel injury, or Equipment and/or property damage, if not properly or adequately supported, secured or otherwise handled.
- Upon entering and occupying Equipment, ensure that additional Personnel are present to provide for immediate egress assistance.
- All inspection, service access ports, doors and inlet and discharge connections shall be periodically inspected, at regular intervals for leaks. Securing mechanisms should be everly tightened as required. Uneven tightening will cause leaks and eventual failure.

**WARNING**

To assure Equipment performance, and proper utilization, it shall be necessary, and/or required to:

- All electrical circuits shall be in accordance with the most current accepted edition of National Electrical Code and/or Code mandated by Local JHA. Use copper conductors only.
- Ensure all electrical service connections are properly grounded and adequately designed for Equipment electrical load.
- Ensure Equipment environs are properly ventilated.
- Proper venting of tanks, products of combustion, components and relief devices.
- Ensure that Equipment is not intended to furnish, or is utilized for, temporary service to the structure, or process, for which it is installed. The Warranty shall not cover any defect in material, component and workmanship during periods of temporary service. Warranty is subject to Equipment inspection and acceptance at time of commissioning by authorized commissioning service provider.
- Equipment shall be installed, and/or supported from non-combustible structural member(s), and/or non-combustible flooring material(s) only.

**DANGER**

DO NOT ATTEMPT, or Permit, Repairs on Equipment while in Service, or Under Pressure. Before attempting to perform any inspection, service, maintenance and/or emergency procedure or repair, it shall be necessary, and/or required to:

- Hazard of Electrical Shock - Disconnect all electrical power supplies. Be advised that more than one electrical disconnect switch may exist to cause, and effect, complete electrical disconnect of all power supplies.
- If so equipped, remove and secure primary combustion safety control device from local central panel to prevent an inadvertent re-start of Equipment.
- Provide conspicuous display of "lock-out tag" notices at entrance to Equipment location and on front of Equipment to ensure observance by other Personnel.
- Permit Equipment to gradually cool down to a temperature, which pursuant to Local Jurisdictional regulations, will provide for proper and safe-efficient discharge to adequately designed drainage system. Do NOT Attempt to hasten this process by addition of cold water. Ensure Equipment has been completely drained and vented prior to opening of any inspection, service access ports and inlet and discharge connections.

**DANGER**

This Equipment has certain design and operating limitations. Personnel shall be advised:

- Equipment may utilize combustible fuel(s), and/or refrigerant, and may utilize, or generate, hot water and/or steam, at elevated temperatures above atmospheric pressure (14.7 PSIA/101.32KPa).
- DO NOT ATTEMPT to operate Equipment other than for the designed service intended and within designed capacity limits.
- DO NOT ATTEMPT to bypass, or otherwise render inoperable any operation, limit, safety control, venting, and/or relief device.
- DO NOT ATTEMPT restart of Equipment unless the failure, or manual reset, condition that occurred is thoroughly investigated, cause identified, and fully corrected, prior to restart.
Label 5. Typical Fuel Burning Equipment Rating Tag

Label 6.

NOTICE

A GAS PRESSURE REGULATOR CAPABLE OF BEING ADJUSTED TO ____ WC MANIFOLD PRESSURE SHALL BE INSTALLED AT THE TIME OF INSTALLATION OF THE UNIT THIS BURNER WAS TESTED ON ____ BTU/CU. FT GAS AS FOLLOWS

LOW FIRE _____ CHF AT ____ WC
HIGH FIRE _____ CFH AT ____ WC

N 76093-A
SECTION I - GENERAL DESCRIPTION

Label 7.

![UL Listed Oil Fired Boiler Assembly Label](image)

Label 8.

**WARNING**

- Allow the boiler to cool before opening any access ways.
- Whenever the rear door, manway, hand holes, etc. are opened, be sure to remove gaskets and replace with new gaskets.
- All such access ways should be checked at regular intervals for leaks, and securing bolts should be tightened as required.
- Tighten bolts evenly—uneven tightening will cause leakage.

**FOR YOUR PERSONAL SAFETY:**

- Read and Understand all Instructions and Warnings [Including all applicable Material Safety Data Sheets (MSDS)] before using any product;
- WHEN PERFORMING MAINTENANCE (INCLUDING BUT NOT LIMITED TO, CUTTING, GRINDING, WELDING, OR CLEANING), WEAR SUITABLE PERSONAL PROTECTION SAFETY EQUIPMENT [EYE, HEARING, AND RESPIRATORY PROTECTION SAFETY];
- Make sure that any material being unbolted or cut is secured and will not free-fall, possibly causing injury or damage;
- Keep hands and body parts from direct contact with Hot Surfaces;
- Make sure footing and body position will not cause a loss of balance in the event of an unexpected occurrence.

Consult the Installation, Operation and Maintenance Manual on any questions relating to proper Maintenance, Installation or Operation of this equipment.

YORK-SHIPLEY GLOBAL

144712
Label 9.

PROBE L.W.C.O. RELAY
RELAY MUST BE RESET
AFTER LOW WATER CONDITION
OR POWER FAILURE.  RESET
BUTTON UNDER COVER.

N-149014-A

Label 10.

CAUTION
REPLACE OIL EVERY 3 MONTHS. USE
COMPRESSOR LUBRICATING OIL IN FILTER.
FILL TO BEAD BELOW 87342

Label 11.

WARNING
Gas Vent Valve

• Run a full size 3/4 inch (or larger) pipe from gas vent valve to the outside of the building.
• No traps are to be provided in the pipe.
• Piping must terminate away from all windows and doors, and provisions must be made to prevent rain and foreign objects from entering vent piping.
WARNING
When Lifting, Use a Spreader Bar to Prevent Damage to the Boiler

Label 12.

IMPORTANT
Be sure to flush your boiler water level control DAILY while boiler is in operation. Failure to follow this procedure can cause the control to malfunction resulting in serious boiler damage.

CAUTION
When flushing control, hot water and steam will flow out of the drain pipe. Controls must be flushed at least once a day while boiler is in operation. Opening blow-down valve also checks the cutoff operation. While burner is on, open blow-off valve. Float should drop. Boiler feedwater system will be turned on and then the burner will stop; hot water and steam will flow out of the drain pipe flushing away sediment.

CAUTION
If burner does not shut off during blow-down, replace control immediately. Continue draining water from control until water is clean. Close valve. Water level should be restored automatically through feed water system.

PART NO. 710636
Label 14.

Remove this Block and
Install Pipe Plug
before Starting this Unit

PART NO. 710651

Label 15.

REMOVE COVER AND
REMOVE PAPER
BLOCKING AROUND
MERCURY SWITCHES.

PART NO. 710652

Label 16.

WARNING
This pump should be used with two pipe system only. It is specifically designed and built to eliminate air from nozzle pipe and minimize after drip.

Do not connect to single pipe system without following instructions, otherwise pump seal will blow.

PART NO. 710654
Label 17. Hot Water Boiler Thermal Shock Warning

**WARNING**

**AVOID THERMAL SHOCK**

Rapid replacement of your boiler's hot water with return water at a temperature below the boiler manufacture's recommendations can cause serious damage to your boiler. DO NOT ALLOW THIS TO HAPPEN. Do not fire the burner until after water flow has been established in all zones and through the boiler.

Hot Water Boilers must be protected from:
1. Low Temperature water return
2. Rapid changes in firing rate when the boiler contains low temperature water
3. Excessive burner cycling.

302956

Label 18.

**DANGER**

**HAZARD OF ELECTRIC SHOCK**

- Disconnect all power supplies before servicing equipment.
- More than one disconnect switch required to disconnect all power within this panel.
- Reset buttons for electronic control & magnetic starter inside panel.
- Wire all circuits NEC Class 1.
- Use only copper conductors.

94367


2-1. Inspection

Upon receipt, check the boiler and all accompanying packages. Immediately make claims to the carrier for all items and/or parts either damaged or missing. In addition, notify York-Shipley Global of all items and/or parts either damaged or missing. Failure to immediately advise and make shortage, or damage, claim to carrier may preclude ability to recover compensation.

2-2. Storage

Keep the unit protected during storage and the installation process. Cover the boiler and related equipment with a tarpaulin, or other suitable cover, as required under the circumstances of the site in a manner that protects the equipment from weather, dust and all destructive or corrosive atmospheres. Take special precautions to protect motors and electrical components from moisture. Store equipment only in areas free from flooding hazard.

Ensure no foreign material enters any component or opening in the boiler shell as such material will adversely affect boiler operation and/or performance.

Failure to adequately protect the boiler will result in the voiding of York-Shipley Global's Warranty, if applicable.

2-3. Boiler Lay-Up

When a boiler is taken out of service, the unit should be cooled until the water is below the atmospheric boiling point or to a temperature suitable for site specific requirements. The boiler may then be drained and flushed out and an inspection should be made to determine what repair work is necessary and what mechanical and chemical cleaning should be done. A decision should then be made to employ dry or wet storage.
Employ the services of a competent and qualified water quality service provider to ensure proper lay-up procedures and safely administer any program to accommodate same.

Whenever a package boiler is taken out of service for any purpose, it should be internally cleaned when put back into service or placed in wet or dry storage. Loose material in the form of dirt, trash, mill scale, or deposits should be removed by washing or other mechanical methods.

2-4. Dry Storage

Dry storage is a procedure preferably for boilers out of service for extended periods of time or in locations where freezing temperatures may be expected during storage.

The cleaned boiler should be thoroughly dried, since any moisture left on the metal surface would cause corrosion to occur on long standing. Precautions should be taken to preclude entry of moisture in any form, into the water side of the unit.

To prevent moisture attack during dry storage, moisture absorbing material such as quick-lime at the rate of 2 pounds or silica gel at the rate of 10 pounds for 1000 gallon capacity may be placed on trays inside the boiler to absorb moisture from the air. The manholes should be closed and all connections on the boiler be tightly blanked. The effectiveness of the materials for such purposes and need for their renewal may be determined through regular internal boiler inspections.

2-5. Wet Storage

Wet Storage is preferable when boilers are to be placed in storage condition for short periods of time or when it is likely that a standby boiler will be needed for service on short notice. The procedure should not be employed for boilers in locations where freezing temperatures may be expected during standby.

The cleaned boiler should be filled to the top using condensate or feed water, either of which should be conditioned chemically to minimize corrosion during standby and closed. Prescribed concentrations of caustic soda and of scavenger such as sodium sulfite may be employed. Concentrations of approximately 450 parts per million (ppm) of caustic soda and 200 ppm of sodium sulfite may be used for this purpose. You should consult your boiler water treatment
company for the specific requirements at your site. Water pressure greater than that of the atmosphere should be maintained within the boiler during the storage period.

NOTE

The percentage of soda and sulfite noted above is greater than recommended for operation of the unit. It will be necessary to completely drain the unit prior to placing it on-line and to treat the water during operation according to the recommendation of the boiler water treatment company employed.
Section III
High Pressure Steam Boilers Installation & Arrangement

3-1. Description of Boiler Room Items

1). Reinforced Concrete Pad

A concrete pad of sufficient thickness, preferably with a reinforced mat is important in the planning of a boiler installation. The wet weights are listed in this section on the Boiler Dimension Charts to assist planning for the proper pad. The pad should be level so that all parts of the boiler skid assembly are firmly in contact with the solid support.

York-Shipley Global strongly recommends that a qualified engineer review the design of the pad(s) used to support all boiler room equipment to meet all federal, state and local codes and site conditions relative to ground conditions and related factors such as seismic conditions, etc.

2). Boiler

York-Shipley Global Series 500C Boilers are of horizontal three-pass dry backed fire-tube design. York-Shipley Global's standard low pressure steam heating boilers models are designed for 150 PSIG pressure. The main firing tube or furnace, where combustion takes place, is generally located near the center of the pressure vessel. The smaller, convective tubes are located around the furnace and make up the 2nd and 3rd pass of the boiler. All joints are welded in accordance with the requirements of The American Society of Mechanical Engineers ("ASME") as set forth in the ASME Boiler and Pressure Vessel Code, an internationally recognized code. York-Shipley Global's low pressure boilers (a boiler which steam or other vapor is generated at 150 psi or less for use external to itself) are fabricated in accordance with Section I, Heating Boilers of the ASME Boiler and Pressure Vessel Code. All boilers and pressure vessels fabricated by York-Shipley Global are built in full compliance with the requirements of the ASME Boiler and Pressure Vessel Code. In addition, the fabrication of each boiler and pressure vessel is performed under the scrutiny of an independent inspector authorized by the National Board of Boiler and Pressure Vessel Inspectors (the "National Board"). In addition, each boiler and pressure vessel is registered with the National Board. Documentation of the inspection and the registration number is found, among other place, on the boiler which is stamped with the inspectors number and the boiler's registration number.
In a water backed boiler, the combustion chamber reversing chamber is comprised of a water cooled arch and a water cooled rear water wall. Access to the second pass tubes is provided from the rear of the boiler to a manway which permits access to the reversing chamber. 2\textsuperscript{nd} and 3\textsuperscript{rd} pass Tubes generally can be removed from the front and 3\textsuperscript{rd} pass tubes from the rear of the boiler.

3). **Steam Outlet Connection**

The standard steam outlet connections on York-Shipley Global Series 500C boilers are 300# flanged. Accessory items, such as header valves, non-return valves and others of similar nature are available in either 300# designs.

4). **Manhole**

One 12” x 16” manhole is provided in accordance with ASME B&PV Code.

5). **Handholes**

Handholes, generally 3-1/2” x 4-1/2”, are also placed in boilers for inspection and maintenance of the internal surfaces of the boiler.

During installation make sure all components have sufficient clearance so that functions of each manhole and handhole, as well as the components, can be maintained.

6). **Test Tee**

Care should be taken to ensure the test tee is not obstructed.

The test tee is provided for the convenience of inspectors when calibrating the steam pressure gauge on all York-Shipley Global steam boilers. It also serves to relieve the vacuum created by steam condensing upon shut down of the boiler.

7). **Lifting Lugs**

Lifting lugs are provided on the top of the shell at the front and rear for lifting the boiler into position. These lugs should be used for all overhead lifting. A spreader bar should be used when lifting from a single point.
WARNING
Do not sling the boiler.

8). Rear Covers and Manway

Water backed boilers are generally provided with a two piece rear access doors which can be removed for inspection, cleaning, and/or the tube removal of the third pass tubes.

Access to the second pass tubes is through a manway which permits access to the reversing chamber, furnace and second pass tubes for inspection, cleaning and maintenance, but not tube removal. The manway provides adequate clearance in the rear for cover removal, manway swing and, if required, rear tube removal for the third pass tubes.

9). Rear Cover Mounting

Rear covers are normally held in place and sealed with studs and nuts.

10). Water Gauge

All steam boilers are supplied with a water gauge to provide a visual indication of the water level within the boiler. The water gauge glass is attached with valved fittings to a water column. The lower gauge glass fitting is provided with a drain connection.

11). Safety (Explosion or Puff) Relief Doors

Optional relief doors are available and mounted in upper rear cover sections.

DANGER
Persons must keep clear of relief doors due to danger of bodily contact by door in the event of a puff or combustion explosion.

12). Flue Gas Outlet

Standard boilers have a flanged vertical connection.
13). Front Access Doors

The front Access Doors are attached with studs and nuts. Removal provides for inspection, cleaning and tube removal. The front cover is also available with optional hinges. Always provide adequate clearance for maintenance, cleanout and front door swing or removal.

14). Rear Observation Port

The combustion chamber manway includes an observation port for viewing the burner flame.

15). Pressure Gauge, Siphon and Cock

All steam boilers are provided with a steam pressure gauge suitable for the design pressure of the boilers. The gauge is fitted with a siphon and shut-off cock and located at the top center of the boiler.

16). Stack Thermometer

An optional thermometer is available. This is mounted in the vertical flue gas outlet.

17). Safety Relief Valve(s)

The Series 500C boiler Series are provided with adequate pressure safety valve(s) as required by ASME code. Standard safety valves are set at the maximum design pressure of the boiler shell, unless otherwise requested. Should the pressure exceed this rating the relief valves open to relieve the excessive steam produced. This prevents boiler rupture.

It is recommended that exhaust steam piping be run to a point outside the building where it can be released without injury to personnel or property. Another practice is to run this piping through the roof.

DANGER

Exhaust steam piping from safety relief valves must terminate where the steam can be released without danger or injury to personnel.
All low pressure units are equipped with side outlet safety valves. Low points in all safety exhaust lines should be dripped to remove all water. On low pressure units the exhaust piping size is the same as the safety valve size.

18). **Left Blank Intentionally**

19). **Jacket and Insulation**

The boiler shell is insulated, jacketed and painted with high temperature enamel paint. The jacket should be protected as much as is possible during storage and installation.

20). **Burner**

All steam boilers have 2 limit controls as standard equipment. One control is the operating limit and is used automatically to turn the burner on and off when the desired operating pressure is reached. The second control is the high (safety) limit used as an additional safety control to prevent the boiler from developing excessive pressure. As an optional feature the safety control can be furnished with a manual reset. Low pressure steam limits have an upper range of 150 psi. The safety limit controls are normally set slightly below the safety valve setting.
When a boiler is equipped with a firing rate motor, either a modulating or a two position high/low and additional control are furnished to regulate the position of the firing rate motor. This control is normally adjusted at a pressure setting lower than both limit controls.

21). **Low Water Cut-Off**

All steam boilers are equipped with a low water cut-off control. This control interrupts the operation of the burner whenever the boiler water line drops below a safe level. The standard low water cut-off (LWCO) is a combination LWCO and feed water pump control all mounted in a water column. The water column includes gauge cocks, water gauge glass, try cocks and drain valves. The water gauge is to provide a visual indication of the water level within the boiler. The water gauge glass is attached with valved fittings to the water column. The gauge glass fitting is provided with a drain connection.

The main consideration for the LWCO is that ample space is provided and no pipes or obstruction be permitted to interfere with their function.

<table>
<thead>
<tr>
<th>IMPORTANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Be sure to flush your boiler water level control(s) daily while boiler is in operation. Failure to follow this procedure can cause the control to malfunction resulting in serious boiler damage and personal injury.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CAUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>When flushing control, hot water and steam will flow out the drain pipe. Control must be flushed at least once a day while boiler is in operation. Opening blowdown valve also checks the cutoff operation. While burner is on, open blow-off valve, float should drop. Boiler feedwater system will be turned on and then the burner will stop; hot water and steam will flow out the drain pipe flushing away sediment.</td>
</tr>
</tbody>
</table>

If burner does not shut off during blowdown, replace control immediately. Continue draining water from control until water is clean. Close valve. Water level should be restored automatically through feedwater system.

<table>
<thead>
<tr>
<th>WARNING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low water cut-off piping must not be insulated.</td>
</tr>
</tbody>
</table>
22). Auxiliary Low Water Cut-Off

The second manual reset low water cut-off can be piped in the same manner and the blow-down valve connected to blow-down piping. Probe type manual reset LWCO controls are typically mounted at top centerline of boiler shell.

23). Forced Draft Fan

All steam boilers are equipped with forced draft blowers which operate independent of high stacks or chimneys. The forced draft blower is generally part of the packaged fuel burning equipment manufacturer’s assembly and provides all the air required for proper combustion.

24). Modulating Linkage

The modulation motor and linkage provides proportioning of the fuel and the air to the burner. This assembly maintains proper fuel to air ratio throughout the entire range of boiler operation.

25). Condensate Return System

The condensate tank is provided to collect all condensate return from the steam system. The tank should be of sufficient capacity to provide all the water required for 10 minutes of boiler operation without adding any make-up water to the tank. This should be equivalent to 15% of the hourly output of the boiler.

Feedwater pumps are directly driven by electric motors, and are used to feed water to the boiler on demand by the boiler level control. The pumps are sized to deliver approximately 1.3 to 2 times the evaporation rate of the boiler at maximum operating pressure.

The feedwater tank must be elevated to create a positive head on the feed water pump. The required head depends on the temperature of the water in the tank and the design of the feedwater pump.

For temperatures above 200°F, consult the factory for correct water level heights and pump selections.
For 200°F water level in the tank should be 7’ from C/L of the pump.  
For 190°F water level in the tank should be 5’ from C/L of the pump.  
For 180°F water level in the tank should be 4’ from C/L of the pump.

The tank is equipped with a gauge glass (item 37) make up valve (item 41), thermometer (item 42) and an opening in the tank to accommodate the installation of other components which might be necessary.

When the temperature in the tank goes below 180°F or when more than 5% fresh make-up water is added to the system, a tank heater assembly should be added to the tank. This assembly consists of a tank heater element and the necessary pressure and temperature control valves (items 38, 39 and 40) to maintain the desired tank temperature and prevent damage to the boiler(s).

When more than 5% make-up water is required, a water meter (item 46) should be installed to indicate the amount of water added to the system. This information is a helpful indication of the amount to water treatment required.

Item 43 shows the condensate line to the tank. This line should be equipped with a wasting tee and valve (item 45) to prevent oil and foreign matter from getting into the tank during initial start-up of the system. High pressure returns should enter the tank at the water line. A connection can be supplied for this purpose.

26). Condensate Vent to the Atmosphere

The condensate return tank should be vented to the atmosphere to prevent the tank from collapsing due to vacuum build-up on shut downs. It will also protect the tank against excessive pressure build up. A pressure relief valve should be installed in the tank as an additional precaution against excessive pressure.

The condensate vent will provide a passage for venting oxygen liberated by the heating of water. The vent will also provide the necessary protection in the event excessive water is returned from the system to the tanks.
The vent should be sized in accordance with the Table 3-1 below. The vent piping should run full size with as few fittings as possible and with no reduction in size or restrictions. The vent piping should pitch upward so water cannot be trapped inside. Precautions must be taken to prevent freezing of the vent line.

<table>
<thead>
<tr>
<th>Connection</th>
<th>Pipe</th>
<th>Tank Gallons</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{3}{4}''$</td>
<td>$\frac{3}{4}''$</td>
<td>22-100</td>
</tr>
<tr>
<td>1’</td>
<td>1’</td>
<td>101-150</td>
</tr>
<tr>
<td>1 ½”</td>
<td>1 ½”</td>
<td>151-350</td>
</tr>
<tr>
<td>2’</td>
<td>2’</td>
<td>351-500</td>
</tr>
<tr>
<td>2 ½”</td>
<td>2 ½”</td>
<td>500 and over</td>
</tr>
</tbody>
</table>

*Height of Condensate vent piping not to exceed 12’- 0” from tank.

NOTE

- Upon start-up, waste (dump) the condensate until all oil is out of the piping system. Upon cleanout of the piping system, condensate may be returned to the condensate receiver tank.

- High pressure condensate should enter the tank below the waterline.

- Low pressure condensate should enter the tank at the top.

IMPORTANT

- Do not put water treatment into the condensate tank feed water.

When multiple installations are made, a common receiver is located in a central position and piped according to the installation drawing. It is recommended that each unit have its own pump, discharge line and pressure gauge and be operated as an independent unit with an independent water level from the float pump switch on the unit. The discharge pump line is to be equipped with a swing check and stop valve. When the condensate tank is higher than the boiler waterline a spring-loaded check valve is also required to prevent the boiler from flooding after shutdown.
27). Steam Piping Main Bleed Trap

During certain periods of operation steam will condense in the header and remain there unless drained. In pressure piping, water caught in the rapid flow of live steam causing hammering condition has been known to cause severe damage and destruction in steam lines and fittings.

Any change in elevation should be provided with drains or automatic traps to drain. Eliminate any possibility of the accumulation of water in the piping.

All traps should be installed with suitable strainers and valves to facilitate cleaning and repair of the traps.

28). Stop Valve

At times it may become necessary to take a boiler off line and allow the others to remain in operation. This is necessary to clean the fire side or water sides of the units or to facilitate normal service of the equipment.

Stop valves allow the unit to be cut off from the entire system without disrupting the other boilers that are needed to provide the steam load. The valve shall be dripped with the trap and accessories when necessary.

29). Non-Return Stop and Check Valves

Non-return stop and check valves are normally required on multiple boiler installations. The stop and check valve assembly will prevent the steam produced by the lead boiler(s) from backing up into those boilers not operating at the same pressures. Without this valve the steam produced by the lead boiler will flow into the steam space of other boilers, condense and eventually flood the remaining units.

30). Insulation, Steam Header and Breaching

It is recommended that all steam and return piping and breaching be insulated. This covering is necessary to limit heat radiation loss. This helps to keep the plant more efficient and cuts down on ambient temperature build up in the boiler room. A good grade of insulation is 85%
magnesium. A desirable covering such as canvas should be used over the insulation to prevent deterioration.

31). Blowdown Tank

A blowdown tank is recommended to allow proper blowdown of all units without affecting the drain or sewer connections. There may be as many as five blowdown connections; surface blowdown, water column blowdown, gauge glass blowdown and one or two bottom blowdowns. These should each be connected to the blowdown tank.

The blowdown tank is vented to the atmosphere to prevent the pressuring of drains and sewers. The tank is equipped with a water valve which blends cold city water with the blowdown products. There is a thermometer to adjust cold water to the steam blowdown product to maintain a control temperature.

City, state and local codes sometimes insist on complete protection against live steam or hot water under pressure from being applied to sewer piping.

<table>
<thead>
<tr>
<th><strong>DANGER</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressurized blowdown water can cause serious personal injury if not controlled.</td>
</tr>
</tbody>
</table>

32). "Y" Type Blowdown

The “Y” type valve is used to regulate the flow of blowdown products from the boiler proper. It is located in series with the quick opening valve positioned down stream from it.

The valve operation controls the amount of water being removed through the blowdown procedure. The quick opening valve is installed as a secondary protection against leaking in the blowdown valve system.
33). Surface Blowdown Valve

Each York-Shipley Global high pressure boiler is provided with a surface blowdown connection. It is located on the standard water line of the unit. Surface blowdown connections can be ordered as optional tapping on low pressure boilers.

The surface blowdown valve is usually a slow opening type with indicator and should be fitted in the piping assembly with other blowdown piping as required. This connection will provide a means to surface blow the water surface or skim within the unit removing any floating foreign matter.

New boilers operated for the first time will have an excess of grease and other compounds present in the water line of the unit. If this is not it will cause foaming and priming of the boilers.

34). Quick Opening Bottom Blowdown Valve

The bottom blowdown valves are connected to openings provided at the bottom of the boiler. The quick opening valve is code required and provides secondary protection to the slow opening valve connected in series with it.

Foreign particles such as rust, dirt, minerals and other elements will eventually find their way back into the boiler. If this material is not removed from the bottom of the boiler the chances of malfunction will increase. This build up of sediment on the bottom of the boiler will eventually begin to cover the boiler tubes and cause them to burn out.

Water treatment compound added to the boiler water will dislodge mineral elements and calcium from the boiler. Water in the area where the unit is to be installed must be analyzed by a competent water treatment organization. Follow their recommendations. Proper water treatment will increase the life of your boiler and assist in higher efficiencies and less down time.

35). Steel Breaching Vent Connection

Breaching should be run as directly as possible. When elbows are necessary they should be as large a radius as possible. Individual breaching should enter the common breaching at a 45°
angle to prevent flue gas back-up to "down' units on a multiple installation. Vents or breathings for other appliances should not be connected to boiler breaching, since other appliances usually depend on natural draft for optimal operations.

**IMPORTANT**
Steel breaching vent connection must be round and not square.

Breaching should be 12 gauge minimum thickness with flanged and gasketed joints and connection to the boiler. A flanged connection is provided at the unit. Vent pipes and breaching should be ROUND rather than square or rectangular to avoid noise and vibration. Vents should terminate at a point where flue gases will not be objectionable.

Dampers or draft regulators should not be installed on jobs with normal conditions.

Breaching should include a cleanout opening at some appropriate location, such as, the end of the common.

All breaching should be insulated for safety and to reduce ambient boiler room temperature.

**IMPORTANT**
All branches from units joining main stack, should enter on a 45° angle to prevent backup of gases to down units.

**CAUTION**
Stack exit must be a sufficient distance above the roof to avoid problems due to wind turbulence (see NFPA 54 and NFPA 31).
36). Stack Cleanout Cover and Deflector

The stack should include a cleanout provision near the bottom and a deflector to the joint where the breaching enters the stack. See Figure 3-1 (page 3-12).

37). Fresh Air Inlet Damper

A burner requires sufficient fresh air for combustion, to avoid smoky fires, soot and carbon which will lower the boiler efficiency. An adequate fresh air opening is necessary for both good combustion and to keep ambient temperature in boiler room below 90°F. When boilers are not operating fresh air is not necessary. A louver type, motor operated, damper may be used for air control. The burner can be inter-locked with the damper motor to prevent burners from starting until dampers are open. Appropriate ventilation should be furnished into the upper section of the boiler room to reduce the ambient temperature. Air inlet openings should be screened.
DANGER
Fresh air inlet must not be blocked or obstructed at any time the boiler is operating.

NOTE
In all cases, fresh air inlet area must meet the minimum requirement of the local (city or state) jurisdictional code.

38). Chemical Feeder

Various types of chemical feeders and/or pumps are optional depending on boiler size and type, characteristics of the water and the type of usage. The chemical company making the water analysis should recommend the type of feeders required to properly dispense their chemicals.
4-1. Combustion

The three basic elements needed to burn a fuel are:
- fuel,
- oxygen and
- heat.

The relationship of the three combustion requirements are illustrated by the combustion triangle in Figure 4-1 below.

**a. Fuel**

The fuel supplies the chemical elements - carbon (C), hydrogen (H) and sulfur (S) which combined with oxygen (Air) to produce heat. The oxygen (Air) must contact the fuel to have combustion.

The more surface the fuel has, the easier it is for the oxygen to contact the fuel. Increasing a fuel's surface makes it easier to mix the fuel and air. Several methods are used to increase the surfaces of the fuels to make it easier for the fuel to mix with air.

Oil is sprayed through a nozzle under pressure to produce a fine mist with large surface area. Heavy oils (thick at normal temperature) are heated so they can be sprayed under pressure through a nozzle to make a fine mist. Natural gas is mixed with air in a burner. Because it is already a gas, nothing needs to be done to increase its surface are. The gas must be evenly mixed with air.
Figure 4-1. Combustion Triangle
The combustion process produces a fire. The fire burns the fuel and changes chemical energy into heat energy. Fuel plus heat plus air make hot gas. Hot gas contains the fuel's heat energy. Figure 4-2 illustrates the combustion process.

![Combustion Process Diagram](image)

**Figure 4-2. Products of Combustion**

The amount of excess air needed depends on how easy it is to mix the fuel and air. Gas can be burned with very little excess air, oil requires slightly more.

To completely burn the fuel, two other things that are needed are:
- proper mixture of fuel and oxygen, and
- enough time for all the fuel to burn.

Complete combustion of a fuel requires:
- proper mixture of fuel and oxygen,
- enough air to supply all the oxygen needed,
- temperature kept above ignition temperature (heat), and
- enough time to let the fuel burn completely.

### b. Heat

Fuels need heat to start the combustion reaction. Heat raises the fuel's temperature until the combustion reaction starts. The temperature at which combustion starts is the ignition temperature. When good combustion is established, the fire produces enough heat to keep the temperature high enough to maintain ignition.

### c. Oxygen

Oxygen is used to measure the amount of excess air. The percentage of O₂ in the flue gas is monitored by instrumentation. This percentage is a reliable indicator of the amount of excess air. The amount of excess air can be controlled by maintaining a set amount of O₂ in the flue gas.
Portable instruments may be used to check the amount of oxygen in the flue gas. Also boilers may be equipped with oxygen recorders to continuously monitor the amount of excess air available. Another method of checking the amount of excess air is to measure the amount of CO\textsubscript{2} in the flue gas. This is not as accurate a method of determining excess air as measuring the amount of oxygen.

**d. Products of Combustion**

If a fuel burns completely with the theoretical air, there is no oxygen in the products of combustion. When all the air is not used to burn the fuel, there is oxygen in the products of combustion. Oxygen in the flue gas indicates that not all the air was used to burn the fuel. Boilers are designed to operate with some amount of excess air. This will insure the complete combustion of all available fuel over the full operating range of the boiler.

### 4-2. Boiler Fluid Flow Paths

The boiler is a complex heat exchanger made up of several systems that are required to work in harmony to efficiently produce the end product of steam. The basic systems that work together to form a boiler are the Water, Fuel and the combustion Air. The operation of the combination of these three dictate the power output of the boiler. To adequately understand the overall boiler system, a detailed understanding of each of the contributing systems must be understood.

**a. Water**

The water to the boiler is the working fluid in the boiler. It provides the heat sink for maintaining cooling to the boiler components. The water is also the source for the steam supplied by the boiler. Water associated with the boiler is viewed in two distinct separate flow paths, the overall and the internal.

The overall flow path of the water to the boiler is an open system. The feedwater comes into the boiler through supply piping to a regulating valve. The regulating valve controls the flow of incoming feedwater to the boiler to maintain adequate level. The water in the boiler is transformed into steam and leaves the boiler to be used by the consumer.

To efficiently operate, the firetube boiler relies heavily on the natural circulation developed internal to the shell of the boiler. This natural circulation flow path is developed by the positioning of the internal baffles and the positioning of the feedwater supply inlet. The internal baffles direct the movement of the water around the tubes in the boiler as shown in Figure 4-3. The internal flow is not a result of an external force like a pump but the result of the heating of the water.

The water changes density when it is heated from the relatively cold feedwater to the high temperature required to change state and become steam. The cold dense feedwater enters the boiler shell approximately 8 inches below the centerline.
The cold dense feedwater is directed down the outside of the boiler shell to the bottom of the shell. The incoming feedwater acts as an insulator cooling the shell and becoming preheated as it sinks to the bottom of the shell. When the water reaches the bottom it is warmer and less dense. From this point on the water is pushed up to the top of the drum by the incoming water. The warm water begins rising through the tubes. The rising water comes in contact with the second pass firetubes. The water is further heated and continues upward around the first pass firetube. The water is mixed with small steam bubbles that are forming and rising to the top of the boiler. The boiling action becomes very violent and closer the water/steam mixture gets to the top of boiler. The water/steam mixture passes around the third pass firetubes. Steam bubbles in the water break free from the water into the boiler steam space. The remaining water mixes with the incoming feedwater and begins to cycle over. Steam rising through the heated water is scrubbed reducing the moisture content to less than one percent. The steam in the steam space moves through the Dry Pan which produces a tortuous path for the steam to follow further reducing the moisture content to less than a half percent.

**Figure 4-3.** Typical Internal Water Circulation
The temperature increases in the boiler water occur in steps. There are three steps that occur in the process. The first is the preheating that occurs in the third pass firetubes where the incoming feedwater mixes with the recycled boiler water and passes over the firetubes. The second increase in temperature comes when the rising water is exposed to the second pass firetubes. The final heating comes when the rising water/steam combination comes in contact with the first pass firetube. The energy required to complete the phase change of the water is absorbed between the second and first passes.

b. Fuel

The fuel supplied to the boiler provides the chemical energy required to produce the heat in the boiler. The supply and regulation of the fuel to the boiler dictates the power output of the boiler.

1) Natural Gas

The fuel supplied to the boiler is natural gas. Figure 4-4 illustrates this flow path. The supply from the utility comes in to the gas pressure regulator at 10 psig. The regulator reduces the gas pressure to within the parameters that are required by the burner. The reduced pressure fuel gas passes through a manual isolation valve. Leaving the manual isolation valve the gas goes through two motor operated valves that provide automatic isolation of gas flow to the burner under unsafe conditions. The gas leaves the motor operated valves it passes through another manual isolation valve to a butterfly valve. The butterfly valve is controlled by a signal from the controller to automatically modulate the fuel flow to the burner.

Upon entering the burner the gas is distributed into the gas ring. The gas in the gas ring is injected into the combustion air flow through the gas ports.

2) Oil

Figure 4-5 illustrates the oil flow path the supply of oil comes into the system from a fuel oil supply tank. The fuel oil pump takes a suction of the fuel oil supply tank and delivers the oil to the burner through a solenoid operated supply valve. Upon entering the burner nozzle the oil can do one of two things, if demand is high enough the oil will be injected into the boiler and a minimum amount will be recirculated back to the oil tank. On low demand most of the oil is returned to the oil tank. The return oil flow path leaves the burner and goes through the return oil solenoid check valve to the metering valve and into the oil tank. The metering valve is operated by the modulating motor which is controlling the firing rate.
SECTION IV - PRINCIPLES OF OPERATION, STARTUP AND SAFETY

Figure 4-4. Typical Natural Gas Flow Path

Figure 4-5. Typical Fuel Oil Supply
c. **Combustion Air**

The Combustion Air System supplies the oxygen to the burner for burning the fuel. The system also removes the spent gases from the boiler. The air in the system is controlled by a series of dampers and fans. Figure 4-6 illustrates the combustion air flow. The combustion air enters the system through an inlet damper. The inlet damper position controls the volume of air introduced into the suction of the forced draft fan. The air entering the forced draft fan is compressed and forced into the burner tube assembly. The burner tube assembly directs the combustion air into the firing tube toward the whirl assembly. Upon entering the whirl assembly the incoming combustion air is directed into a vortex pattern to promote proper mixing. The combustion gas, fuel mix and fire in the firing tube. The hot gas and combustion by-products are forced through the firetubes.

![Combustion Air Flow Diagram](image)

**Figure 4-6.** Combustion Air flow

The hot gas flow in the firetubes is a three-pass flow. The first pass is the firing tube through the center of the boiler to the rear refractory wall (arch). The rear refractory wall redirects the hot gas flow toward the second pass tubes on the bottom of the boiler shell. The second pass tubes carry the hot gas forward to the turning box area. The turning box directs the hot gas into the third pass firetubes. The third pass firetubes carry the hot gas on the final pass to the exhaust stack. The combustion gas is exhausted into a stack and returned to the atmosphere.

### 4-3. **Boiler Thermodynamics**

Water is a compound of hydrogen and oxygen. It is a liquid at certain temperatures and pressures, a vapor (saturated steam) under other conditions and a gas (superheated steam) under still different conditions. Changes in temperature and pressure will affect the points where water changes phases. For example, Table 4-1 shows how the boiling point of water changes at different pressures.
Table 4-1. Temperature Pressure Relationships

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Boiling Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>.7365 psia</td>
<td>1.5 &quot;Hg</td>
</tr>
<tr>
<td>4.91 psia</td>
<td>10 &quot;Hg</td>
</tr>
<tr>
<td>14.7 psia</td>
<td>0 psig (atmospheric)</td>
</tr>
<tr>
<td>100 psia</td>
<td>85.3 psig</td>
</tr>
<tr>
<td>500 psia</td>
<td>495.3 psig</td>
</tr>
<tr>
<td>1000 psia</td>
<td>985.3 psig</td>
</tr>
<tr>
<td>2000 psia</td>
<td>1985.3 psig</td>
</tr>
<tr>
<td>3000 psia</td>
<td>2985.3 psig</td>
</tr>
<tr>
<td>3206 psia</td>
<td>3191.3 psig</td>
</tr>
</tbody>
</table>

a. **Water Reactions**

However, water has one major function in the package boiler -- to transfer energy from one system to another in the form required by the end user.

Figure 4-7 show a thin metal piston lying over a water surface and exerting insignificant pressure on the water. The piston is free to slide up and down, but it allows none of the steam formed to escape.

In Figure 4-7a, the container holds one pound of water (about one pint) at a room temperature of 80°F. Now consider that heat was applied and the water has absorbed heat energy to where its temperature just reaches 212°F.

Figure 4-7b shows that the absorption of heat energy caused the water to expand. The water was heated from 80°F to 212°F or a 132°F temperature rise. Since it takes one BTU to heat one pound of water one degree Fahrenheit, the water has absorbed 132 BTU of heat energy.

At 212°F, bubbles form at the bottom of the container and create a transparent vapor over the boiling water, as shown in Figure 4-7c. A thermometer placed in the steam will read exactly the same temperature as the boiling water. Steam at the same temperature of the boiling water is called "saturated steam".

If we continue to slowly apply heat until the last droplet of water has evaporated, the container holds only saturated steam at atmospheric pressure and 212°F. The original volume of liquid water has increased from about 1 pint of water to approximately 27 cubic feet of steam. Figure 4-7 d.

Figure 4-7e shows the same container being placed into a pan containing 10 pounds (approximately 10 pints) of water at 80°F. Since the steam is at 212°F and the water is at 80°F, heat transfers and the steam starts to condense.
At the moment all steam has condensed, but the water temperature is still 212°F, the water temperature in the pan will have increased from 80°F to 177°F. This 97 degree temperature rise for 10 pound of water represents a 970 BTU energy transfer:

- 10 pounds (97 degrees) = 970 BTU of heat energy. The one pound of steam released 970 BTU's in changing from vapor at 212°F to liquid at 212°F.

1) Water expands when heated. When equipment or piping is filled with water and then heated, its pressure or volume (or both) will increase. Failure to compensate for these increases can lead to equipment failure and subsequent injury to personnel.

2) One BTU of energy is required to heat one pound of water one degree Fahrenheit. However, the figure changes slightly at higher temperatures and pressures.

3) 970 BTU’s of energy are required to convert one pound of water to one pound of steam at atmospheric pressure. 970 BTU's of energy will be released if one pound of steam is condensed to one pound of water at atmospheric pressure.
The amount of energy needed to convert saturated water into saturated steam is called the latent heat of vaporization. The amount of energy released when saturated steam condenses to saturated water is called the latent heat of fusion. The latent heat values equal one another as long as the system pressure remains constant. Table 4-2 shows how the latent heat values change at different pressures.

**Table 4-2. Heat of Vaporization**

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Latent Heat of Vaporization/Fusion (BTU's)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10&quot; Hg 1100 Atmospheric</td>
<td>970</td>
</tr>
<tr>
<td>100 psia</td>
<td>888</td>
</tr>
<tr>
<td>1000 psia</td>
<td>649</td>
</tr>
<tr>
<td>2000 psia</td>
<td>463</td>
</tr>
<tr>
<td>3000 psia</td>
<td>217</td>
</tr>
<tr>
<td>3206</td>
<td>0</td>
</tr>
</tbody>
</table>

By representing the above experiment with water at 465 psi (normal drum pressure), the same principles can be demonstrated.

As heat is applied, the water expands. Temperature increases to 212, 214, 230, and 300°F, but nothing seems to happen except that the water expands slightly. Finally, at about 460°F, bubbles of steam begin to form. At 465 psi, water must be heated to 460°F for the change of state to occur. If heat is added until the moment all the water has changed to vapor, the steam volume is much less than the volume would be for steam at atmospheric pressure. The measured volume would be about 1 cubic foot, as compared to 27 cubic feet for steam at atmospheric pressure. The advantage of high pressure steam is that it contains much more energy per unit volume.

By applying additional heat after all the water has evaporated, the temperature begins to increase above 460°F. Above this temperature, the steam becomes superheated rather than saturated. The more superheat contained by the steam, the higher its internal energy.

This increase in internal energy is evidenced by the steam's increase in temperature. From the standpoint of efficiency, the more superheat, the higher the efficiency of the plant cycle.
b. **Heat Transfer**

Heat transfer is continuous throughout the boiler during operation. The majority of heat transfer within the package boiler occurs in one or more of the following processes:

- conduction,
- convection, or
- radiation.

1) **Conduction**

Conduction is the transfer of heat from a hot object to a colder one where there is physical contact between the two objects. Heat transfer by conduction requires a heat transfer medium (any object or material) and cannot occur through a vacuum. In conduction heat transfer, the increased motion of the molecules in the hotter object, increases the molecular activity within the colder object. This process will continue as long as a temperature difference exists between the two objects.

The total quantity of heat transferred depends on several factors:

- the total area of the transferring surface,
- the temperature difference across the material,
- the amount of time the materials are in contact, and
- the thermal conductivity of the materials.

2) **Convection**

Convection is the transfer of heat between a moving fluid and any other material. Although convection is often considered a method of heat transfer, it is more accurately described as a "fluid flow" where heat is transferred by conduction. For example, Figure 4-8 shows a boiler tube receiving heat from hot flue gases. As the hot gases pass by the tube, the metal is heated by conduction when hot gas molecules contact its surface. Thus, the effect of convection is to promote contact between the hot and cold substances, and increase the amount of heat transfer. Without convection, there would be little heat transfer to, from,
Convection is classified as either "natural" (hot air or liquid rising because it is lighter than the surrounding air or liquid), or "forced" (a pump moving liquid, a fan moving hot gases, or steam moving through a pipe).

3) Radiation

Radiation is the transfer of heat by emitting electromagnetic waves (also called photons of energy). Any object at a temperature above absolute zero emits radiant energy in tiny amount called photons. These photons of radiant energy can travel through a perfect vacuum (such as from the sun and stars to the earth).

Radiant energy transfer occurs throughout the plant. In the furnaces, radiant energy heats the steam and water pipes, which then transfer heat to the steam and water. The flame temperature in the boiler may reach 2500°F. At this temperature, the radiant heat transfer within the firebox is very high.

Radiant energy transfer occurs only from a hotter body to a colder body. Two bodies at the same temperature will interchange photons but no net energy transfer will occur. When radiant energy (photons of energy) encounters a body, three things can happen:

- the radiation can be reflected;
- the photons can pass through the material; and
- the photons of energy can be absorbed. When the photons of oncoming radiant energy are absorbed, the random kinetic energy of the molecule which absorbed a packet of energy is increased, and the temperature rises.

The rate of radiant heat transfer depends upon

- the temperature of difference between the radiating body and the absorbing body, and
- the characteristics of the material.

For example, a person sitting near a fire is warmed by radiant heat although the air in between remains relatively cool. Radiant heat passes through air, glass and water without increasing its temperature because transparent materials are poor absorbers of radiant energy.
4-4. Instrumentation

The instrumentation that the operator encounters on a daily basis is the only means of communicating with the package boiler. Proper operation of the boiler requires the operator to fully understand the condition of the boiler and its auxiliaries.

a. Pressure

• Fuel Supply (GAS) The system has two pressure instruments. Both of the instruments are switches. The switches are for high and low gas supply pressure.

• High Gas Pressure The diaphragm controller monitors the supply gas pressure to the burner after the regulator and gas valves.

• Low Gas Pressure The diaphragm controller monitors the supply gas pressure to the burner after the regulator and before the gas valves.

Both pressure indications give input to the Boiler Safety Circuit.

• Fuel Supply (OIL) The fuel oil system has two pressure instruments. Oil pump discharge and return line pressure.

• Pump Discharge The discharge pressure gauge provides the local indication of the amount of fuel oil being supplied to the burner.

• Return Line The return line pressure gauge provides local indication of the amount of fuel oil being returned to the tank. This also provides an indirect indication of the power level of the boiler during modulating conditions.

• Burner Control The boiler steam pressure is sensed by a pressure control.

b. Temperature

The package boiler can be equipped with stack temperature indication. The boiler stack can have a stack thermometer for local monitoring. The indication provides guidance for maintaining firetube temperatures high enough to prevent condensation in the firetubes and limit the need for cleaning.
c. **Flow**

The package boiler can be equipped with an air flow safety switch for monitoring the forced draft fan condition. The switch is a differential pressure switch. It provides inputs to the Flame Control circuit for indication of blower failure.

d. **Level**

- **Boiler Water Level Sight Glass** All steam boilers are provided with a water gauge to provide a visual indication of water level. The sight glass is located on the right side of the boiler on the primary LWCO.

- **Auxiliary Low Level Cutoff Switch** The optional switch is located on the left side of the boiler. It is a float switch. When shell water level is below the safe level the switch sends a signal to the Flame Control circuit to shutdown the package boiler.

- **Low Level Cutoff Switch** The switch is located on the right side of the boiler and is the standard primary control input for water level. It is normally a McDonnell & Miller 157 series float switch. Additional types are Clark Reliance probe level controller.

- **Boiler Water Level Control** The boiler water level is controlled by a float switch located on the right side of the boiler. The float actuates a mercury tube that operates the feedwater pump when water level falls below a predetermined level. Standard Control used is a McDonnell & Miller Series 157.

4-5. **Controls**

Boiler controls are used to automatically regulate the major processes occurring in the boiler during normal start-up, operation and shutdown. Parameters such as level, pressure, flow and component position provide the inputs necessary for these controls. The following discussion covers the associated controls for burner operation and flame safety.
a. **Burner Controls**

Terminology

- **High (Safety) Limit Control** is a pressure (steam) or temperature (water) control used as a safety feature to prevent the boiler from developing excessive pressure or temperature. This is often called only a limit control (no reference to “safety” or “high”).

- **Operating Limit Control** is a pressure (steam) or temperature (water) control, used to operate a burner when the pressure or temperature reaches a certain set point.

- **Day-Night Control** is a pressure control used to reduce the system steam pressure for overnight operation. It is wired with a SPST manual switch in parallel with it in the limit circuit to over-ride the operating limit control.

- **Summer-Winter Control** is a temperature control used to maintain boiler water at a temperature below the steaming point during the summer in order to provide only boiler heating (rather than system heating) usually for heating domestic hot water coil in the boiler. It is also wired in parallel with a manual SPST switch in the limit circuit to over-ride the operating limit control.

- **Low Fire Hold Control** is a pressure or temperature control used on enforced low fire start burners to keep the burner on low fire for a prolonged time period usually on cold starts to avoid firing the full capacity of the burner into a relatively cold boiler.

- **High-Low Firing Control** is a pressure (steam) or temperature (water) control used to switch the burner operation from high fire to low fire and back to high fire as required by the demand for pressure or temperature from the system.

- **Two Stage Firing Control** is often used to describe a high low control. It is not widely accepted and not as descriptive as the high-low terminology.

- **Modulating Firing Control** is a pressure or temperature control used to change the burner operation to a rate determined by the demand for pressure or temperature from the system. The function of this control is similar to a high-low control except that it is capable of positioning the burner firing at any required position between high and low fire, as well as, at either extreme. It should be used only in reference to full modulation and is used on systems with low fire start and a motor operated linkage system.

The primary purpose of the burner control system is to regulate the firing rate in the boiler during normal operation. Firing rate is controlled to insure that the amount of energy added to the boiler by the fire is equal to the energy removed from the boiler in the steam or hot water.
The burner control system uses boiler steam pressure to determine the amount of energy being used by the system. As the system uses more steam or heat (energy) than the boiler is producing, the pressure or hot water temperature in the boiler will start to drop. The burner control will sense this pressure or temperature drop and interpret it as a need for more fire. The controller will increase the amount of air and fuel being supplied to the burner to increase the firing rate. This increases the amount of energy added to the boiler, causing the boiler to produce steam at a faster rate. This increase in steam or hot water production matches the additional steam or hot water required by the system stopping the pressure or temperature drop and holding the firing rate at the new higher value. If the system has a reduction in steam or hot water demand, the pressure or temperature will increase and the controller will reduce the firing rate.

The "brains" of the burner controls is the Flame Safeguard Control. It is basically a small computer which has been programmed to:

- Position the combustion air supply damper to a high fire position during the boiler start sequence. This assures a maximum air flow rate (purge) through the boiler to remove all explosive gas mixtures prior to lighting the burner.

- Position the combustion air supply damper and fuel volume control valve to a low fire position during the boiler start sequence. This is done after the purge and before the pilot is lit to insure the burner ignites at its lowest firing level.

- Control the position of the combustion air supply damper and fuel volume control valve, to control (modulate) boiler firing rate during normal operations. A circuit interlock low fire hold prevents the controller from shifting to the modulation mode until a minimum steam pressure or temperature has been established. This insures a controlled heat-up on the boiler during a cold startup. Low Fire Hold operation is external to Flame Safeguard (FSG) control. FSG shifts to AUTO mode at the same point on each cycle. Low Fire Hold, when used, stops modulation when pressure falls below setpoint.

- Provides an input signal to the flame safety controls to shutdown the burner if the steam pressure in the boiler reaches an upper operating set point. This ensures that if the pressure or hot water temperature continues to increase with the burner at minimum firing, the burner will shut down before an unsafe pressure or hot water condition is reached.

- Position the combustion air supply damper to the low fire position during the boiler shutdown sequence. This occurs between the time the burner is secured and the combustion air blower is stopped. This allows air flow (purge) through the boiler to remove all explosive gas mixture prior to securing the boiler.

The steam pressure or temperature input to the controller is provided by a pressure or temperature control. Air and fuel modulation is accomplished by a modulating motor. This motor receives a position signal from the modulating controller and positions both the supply fan damper and the fuel volume control valve (gas-butterfly, oil-metering) through a set of drive linkages.
### 4-6. Flame Safety Control

A furnace explosion is the ignition and almost instantaneous combustion of highly inflammable gas or vapors in the boiler. It can cause a greater expansive force on the boiler than the boiler is designed to withstand. Minor explosions, called puffs or blowbacks, can blow flames from all doors and covers. Anyone in the flame path can be seriously burned. Major explosions can shatter observation ports, blow off doors, throw refractory through walls and roofs and even demolish boiler housings. The main causes of explosions are:

- flame failure with no resulting fuel isolation,
- insufficient purge prior to light-off,
- faulty fuel regulating controls,
- fuel shut-off valve leakage,
- loss of furnace draft,
- faulty ignition system, and
- human error.

The flame safety control is designed to help prevent any condition in the boiler which could result in a boiler explosion. It is an arrangement of flow controllers, pressure sensors, timers and flame detection devices that will stop the energy input into a boiler when an unsafe condition exists. It also programs the operation of the blowers, dampers, fuel valves and ignition sources in the burner system to energize them when they are needed and in the proper sequence.

There are three basic types of flame sensors used to detect the presence of fire in the boiler. They are ultraviolet, infrared and rectifying. The types all perform the same function but use different operating techniques.

#### a. Ultraviolet Detector

The detector is a sealed, gas filled, ultraviolet-transmitting envelope containing two electrodes which in use are connected to a source of AC voltage. When ultraviolet (UV) radiation of sufficient energy (at wave lengths shorter than those in sunlight at the earth's surface) falls upon the electrodes, an electron is released and the inter-electrode gas becomes conductive so that current flows from one electrode to the other. The current flow starts and ends abruptly and is known as an "avalanche". A very intense source of UV radiation will produce several hundred avalanches or pulses per second. With less radiation there will be a lesser number of pulses per second, varying in number and occurring randomly. Upon total disappearance of flame, the detector output ceases, excepting for very infrequent single pulses caused by cosmic rays, to which the circuitry does not respond.

Some of the flame sensors employ a self-checking system. Refer to Figure 4-11.

A magnetically operated shutter mechanism periodically blocks the flame radiation from the UV detector.
Self-checking control de-energizes flame relay if
1. any electronic component fails
2. flame signal is absent or continuous for any other reason.

Figure 4-11. UV Detector

The pulses from the detector tube are passed to a transistor type pulse amplifier and are integrated in a capacitor. When the integrated voltage reaches a predetermined trigger level, a transistor switch energized the flame responsive relay. If the integrated voltage falls below a predetermined level for a period of between 2 and 4 seconds, the transistor switch turns off and the flame relay is de-energized.

The flame failure response time is the same regardless of the intensity of the flame prior to flame out.

A voltmeter (20,000 ohms per volt, 10 volt scale or higher) connected to the test jacks indicates a measure of the flame intensity. Under normal operation, there is a periodic drop in test jack voltage due to the scanner shutter operation.

b. Infrared

The active element of the detector is a lead sulfide (PbS) semiconductor whose electrical resistance instantaneously changes in accordance with the amount of infrared and visible radiation it receives from sources within its view. Such radiation originating in a combustion chamber may consist of a steady radiation from hot refractory or metal and an average value of flame radiation which continuously fluctuates in magnitude by an amount and at a rate which are functions of the type of fuel and combustion conditions. When a DC voltage is impressed across the cell and a series resistor, the fluctuation of cell resistance corresponding to fluctuation of flame radiation produces a fluctuating voltage across the cell. This voltage is termed "flame signal" and is fed to an amplifier.

The amplifier responds to a fluctuating voltage, but not a steady one. It therefore responds to a fluctuating flame signal but not to a steady refractory signal. Further, it is "tuned" for maximum response at a frequency of 10 cycles per second (a fluctuation rate found in all flames) and has relatively little response at power line (60 cycle) and very low (1 cycle) frequencies. When amplified flame signal exceeds a given magnitude, it causes energization of a flame relay.
 Whereas the system does not “detect” hot refractory, excessive steady radiation reduces flame signal. The same effect results from excessive scanner temperature. To avoid nuisance shutdowns, it is important to avoid sighting hot refractory and to keep scanner temperature low (never over 125°F).

c. Rectifying Flame Sensors

1. Photocell

A well-defined and easily sensed characteristic of flames is luminosity. This is particularly important where it is not feasible to insert an electrode directly into high temperature flames. In such cases a photocell, which is mainly sensitive to the blue portion of the flame spectrum (blue predominates in a spectrum of oil flame) and extremely insensitive to extraneous light emitted from incandescent brickwork, etc., is used as a sensing element to introduce proper resistance values to the input circuit of the appropriate flame signal amplifier.

The photocell is sighted at the flame. Advantage is taken of the fact that the photocell is a natural rectifier. When light from the flame strikes it, the photocell produces rectified current from the applied alternating current.

2. Rectifying Rods

The system operates on the flame-rectification principle. This principle is based on the fact that a gas flame is capable not only of conducting an electric current, but also of rectifying an alternating current. The system utilizes this principle by applying a small alternating current to the rectifying rod and the ground to the flame. When the flame is present and in contact with the rod electric current is conducted to the control relay.

The relay recognizes the presence of a flame only if it receives a rectified current from the flame-electrode. When flame is present the output current will energize the control relays. On flame failure, no rectified current can be produced, the output current will drop to zero and the control relays will be de-energized.
4-7. **Combustion Program Controller**

The microprocessor based flame safety and burner management system is designed to provide the proper burner sequencing, ignition and flame monitoring. In conjunction with limit and operating controls, it programs the burner/blower motor, ignition and fuel valves to provide for safe and proper burner operation.

On safety shutdown it will advise the operator that the control is "locked out" and indicate the cause. It also provides for prepurge timing, recycle interlocks, high fire proving interlock and trial for ignition timing for the main flame.

The following is a listing of functions by the flame safety control listed in the sequence which they are performed. The sequence begins with a normal startup, continues through boiler operation and concludes with boiler shutdown. Any safety shutdown is described in the appropriate spot in the sequence. Whenever the program locks out, it must be reset on the Control. This will re-initialize all components and restart the program from the beginning.

1) Breakers are closed and blower is on at the controller.
   a. Program signals modulating motor to low fire position.

2) Operation switch placed in the run position.

3) Program checks the following safety limits are met. If any one of them is not met, the control program will stop all further processes and the burner will not start.
   a. High gas pressure    Gas pressure at the inlet to the gas flow control valve is within safe limits.
   b. Low gas pressure    Gas pressure at the supply pressure regulator is adequate.
   c. Low Water Cutout  Boiler water level is above a minimum safe level.
   d. Auxiliary Low Water Cutout (if supplied)  Backup verification of proper water level.
   e. High Boiler Pressure or Temperature  Boiler steam pressure is below a maximum safe limit for boiler operations.
   f. Operating Boiler Pressure or Temperature  Boiler pressure is below the normal operating high limit determined by the controller.
4) The main fuel valve is in the closed position. This indication is provided by a position indicating switch on the valve stem.
   a. If the valve is not closed, the program will lockout the controller and the startup sequence will stop.

5) With the main fuel valve closed the program will
   a. Start the combustion air blower
   b. Position the modulator to high fire, opening the supply damper fully.

6) The program checks for proper air flow using a pressure switch in the combustion air supply.
   a. If the air flow is not correct, the program will lockout the controller and startup sequence will stop.

7) The modulator is checked in the high fire position.
   a. The program will wait a maximum of 10 minutes for this interlock to be satisfied before it locks out.
   b. If the interlock is made before the 10 minutes is up, the program times a 30 second purge.

8) Program sends a modulator to low fire
   a. The program times a 30 second low fire purge

9) The program checks to insure the modulator is in the low fire position
   a. The purge will continue until the low fire interlock is made
   b. If the interlock is not made within 10 minutes, the program will lockout.

10) The program provides power to the ignitor and opens the pilot fuel valve.

11) The program checks for an established flame at the pilot.
   a. If a proven flame is not detected within 10 seconds, the pilot fuel valve will close, the ignitor will de-energize and the program will lockout.

12) The main fuel valve is opened.
   a. The program continues to check for proven flame.
   b. The ignition term #5 (light oil and gas) is secured 10 seconds after the main fuel valve is opened.
   c. The ignition term #6 (heavy oil #6) is closed 15 seconds after the main fuel valve is opened.
   d. If main flame is not detected at the end of the main trail for ignition, all fuel valves will be shut and the program will lockout.

13) The program sends the modulator to automatic control on the flame controller.
14) The presence of main flame is continually checked during normal firing.
a. If main flame fails at any time during normal firing, all fuel valves will be closed within 4 seconds and the program will lockout.
b. If combustion air supply is lost, power to the main fuel valves will be secured and they will shut. This will be detected as an interlock failure with the resultant lockout.

15) The boiler will remain firing until:
a. A loss of flame causes lockout
b. One of the safety limits listed in Item 3 above is reached, initiating a normal shutdown sequence.
c. The normal high pressure (low load) shutdown signal from the controller initiates a normal shutdown sequence.
d. The operational switch is positioned to the off position initiating a normal shutdown sequence.

16) In a normal shutdown the program sends the modulator to low fire.

17) The main fuel valves are shut.

18) After 15 seconds the combustion air supply blower is secured which completes the boiler shutdown.

The flame in the furnace is "seen" by a lead sulfide infrared detector. The detector is constructed such that infrared light changes the voltage output of the detector which is sent to an amplifier. The amplifier responds to a fluctuating voltage, but not a steady one. This makes it possible to see the fluctuating signal from a flame and ignore the steady signal from hot refractory.

a. **Normal Cycle Startup**

*Note: For direct spark ignited oil burners, substitute the words Main-oil Valve for Pilot Valve.*

1. Constant 120 VAC should be available to the L1-L2 terminals only on the wiring base.

2. The operating control circuits will close, signaling the burner to start its firing sequence.

3. Assuming the fuel valve end switch is closed, the burner/blower motor circuit is energized. The running interlock (limit) circuit will close (e.g.: all limits, interlocks, etc. are proven).

4. The firing rate motor (Modulator Motor) is driven toward the high purge open damper position.
5. When the firing rate motor reaches its open damper position, the Hi Purge switch
    closes and initiates the prepurge interval of 30 seconds. If the circuit does not
    close, the program will hold in this position for ten minutes waiting for it to close. If
    it does not, the control will lockout.

6. When the prepurge is completed, the firing rate motor is driven toward the low
    purge damper position.

7. Following the minimum 30 second delay (to permit the firing rate motor to
    get to the low fire position) the control will wait for the low fire switch to
    close. When it closes, the trial for ignition sequence will start. If after ten
    minutes, the circuit is not closed, the control will lockout.

8. The trial for ignition period known as PTFI (Pilot Trial for Ignition) is ten
    seconds in duration. If no flame is detected after 10 seconds, the control will
    de-energize and lockout. If flame is detected during this 10 second period,
    the main flame trial for ignition sequence will start.

Note: When the flame is detected, the message center will provide a constant readout of the
signal strength.

<table>
<thead>
<tr>
<th>Flame Signal</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0-9</td>
<td>Not Acceptable</td>
</tr>
<tr>
<td>10</td>
<td>Minimum Acceptable</td>
</tr>
<tr>
<td>20-80</td>
<td>Normal</td>
</tr>
</tbody>
</table>

9. With flame proven at the end of PTFI, the main flame trial for ignition
    (MFTI) period begins.

10. The firing rate motor is now sent to the auto position and is under the command of the
    proportional controller. The message center displays a read-out of the
    flame signal.

b. Normal Shutdown

1. When the operating control circuit opens, the main fuel valve is de-energized.
   The firing rate motor is driven to the low purge position.

2. Following a 15 second post purge, the burner/blower motor is de-energized.

3. The burner is now off and the message center displays the burner operating
    history for 2 minutes and then the message center displays the message “OFF”.

4-39
4-8. **Boiler Operation**

The following section discusses good operating procedures and practices. These practices will be presented in the condition of the boiler operation that the operator will most likely experience them. The practices are generic in nature and will apply to many other situations that could occur. It is impossible to predict all the possible combinations of operating conditions that could occur during package boiler operations.

There is more than one correct way to startup or shutdown a boiler. However, by establishing a standard method for each function we can ensure that it is done properly every time, help to prevent mistakes when turning over the operation in the middle of a task at shift change time, and improve communications when procedure changes are required due to new equipment additions, changes in plant requirements and other parameters that impact the operation.

4-9. **Boiler Prerequisites**

1) Complete a boiler walk around to verify the physical integrity of the boiler and its support components prior to startup.

2) Verify that the natural gas supply to the main supply and ignitor gas lines are available.

3) Adequate make up water available to fire the boiler.

4) Electrical systems in service.

5) Compressed air system in service.

6) Intake air filtration systems clean and ready for use.

7) All "cold" steam line drains open

8) All maintenance conditions returned to normal and maintenance restrictions removed.

4-10. **Startup**

1) Determine the type of startup required:
   
a. Cold startup the boiler and components are at ambient temperatures and have not been operated for a significant time frame, i.e., maintenance shutdown.

   b. Warm startup the boiler and components have recently been in operation and do not require soak or hold points for the equipment to come to operating temperature.

2) Determine if the shell side of the boiler needs to be filled initially or level raised to proper operating levels. Close all boiler drains, water column and gauge glass blowdown valves. Open the shell vents, water columns and gauge glass isolations, and shell pressure isolation valves.
3) Align the boiler control systems and commence a startup. Take a complete set of operating data logs to record the initial starting conditions. Energize the control systems and start the boiler into the operating mode.

4) During the automatic boiler startup operation continuously monitor the boiler and support systems for proper behavior. Make continuous walking tours around the boiler to verify the integrity of the boiler and its support components during heat up and pressure increases.

5) As the boiler is warming up to operating temperature and pressure, maintain the shell water level in the operating range using blowdown or steam line drains.

6) When the boiler is warmed up and steam pressure is within twenty pounds of system steam pressure, shut any remaining steam drains, place the water traps in service and open the steam supply valve to the system.

7) Take a complete set of operating logs to establish the base parameters for monitoring the package boiler during loaded operations.

4-11. Normal Operation

The operator on shift during normal power operations is the operator most subject to encounter a boiler problem. The reason behind this is that human nature allows us to become complacent when conditions seem to be stable and unchanging. The interest level and the attention to detail becomes very relaxed, "its in AUTO".

There are ways that the operator can combat this common problem through good watch standing principles:

1) Examining the operating logs for trends can produce a good indication of a problem that is waiting in the wings.
2) Frequent and complete tours of the operating equipment will also yield any problems that are approaching.
3) Maintain a questioning attitude about the conditions of equipment in operation around your work space.

WARNING

A good operator must take action -- not reaction -- to problems in the operation of a boiler.
4-12. **Shutdown**

When the plant conditions dictate that the package boiler is no longer needed for supplying process steam the unit may be shutdown. The initial actions required to shutdown the boiler are the same until the point is reached when the shutdown is for a long term or short term duration.

1) Verify that the boiler is no longer needed to supply process steam to the plant.

2) Reduce the load on the boiler to the minimum load level then position the Flame Control Circuit to the shutdown position. The Flame Control circuit will secure the fuel supply to the burner.

3) The boiler will go into a purge mode to remove all the combustion gases from the firetubes and begin the unit cool down.

4) The operator should monitor the steam pressure from the unit and close the steam supply valve when the unit can no longer supply the minimum pressure steam.

5) Open the steam line drains and continue to feed and steam the unit to cool off the shell.

6) When the unit is no longer producing steam secure the feedwater to the shell after raising the water level to the bottom of the operating band.

7) If the unit is to be shutdown for a long term, when the unit has reached ambient temperature open the boiler drains, water column and gauge glass blowdown valves.

4-13. **Boiler Safety**

The purpose of this section is directed to safety and the inculcation of proper caution based on knowledge to supplement the natural instinct of self-preservation which, when impaired by ignorance, fatigue or negligence can lull one into a false sense of security.

**a. Safety Resources**

Every steam boiler and all its fittings and attachments shall be properly maintained and operated safely. It shall not be used unless it has been examined in the prescribed manner and within the prescribed period. This section does not provide the necessary particulars for the prescribed periods. However, that information can be referenced in the "Statutory Instrument Manual" under the section entitled "The Examination of Steam Boilers Regulations".
The ASME Boiler Code and the National Board of Boiler and Pressure Vessel Inspectors Inspection Codes are important source documents for legal requirements in the various states and municipalities that have adopted boiler safety laws. In addition to maintaining active boiler and pressure vessel committees in order to keep the published codes up to date with developing technology, the ASME issue to qualified manufacturers, assemblers, material suppliers and nuclear power plant owners Code symbol stamps indicating that the manufacturer has received authorization from the ASME to build boilers and pressure vessels to the ASME Code.

Most areas of the United States and all jurisdictions on Canada require that high pressure boilers be subjected to periodic inspection by an authorized inspector. In most jurisdictions, this consists of annual internal inspection of power boilers and bi-annual inspection of heating boilers and usually of pressure vessels for those states that have adopted laws on low pressure boilers or unfired pressure vessels. If the results prove satisfactory, the jurisdiction issues an inspection certificate authorizing use of the vessel for a specific period.

b. Safety Rules

Table 4-4 below lists boiler safety rules based on past accidents.

<table>
<thead>
<tr>
<th>NEVER</th>
<th>ALWAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEVER fail to anticipate emergencies. Do not wait until something happens to start thinking.</td>
<td>ALWAYS study every conceivable emergency and know exactly what moves to make.</td>
</tr>
<tr>
<td>NEVER start work in a strange plant without tracing every pipe line and learning the location and purpose of every valve.</td>
<td>ALWAYS proceed to proper valves or switches rapidly but without confusion in time of emergency.</td>
</tr>
<tr>
<td>NEVER leave an open blowdown valve unattended when a boiler is under pressure or has a fire in it.</td>
<td>ALWAYS check the water level in the gauge glass with the gauge cocks at least daily and also at any other time you doubt the accuracy of the glass indication.</td>
</tr>
<tr>
<td>NEVER allow sediment to accumulate in gauge glass or water column connections. A false water level may fool you.</td>
<td>ALWAYS blow out each gauge glass and water Column connection at least once each day.</td>
</tr>
</tbody>
</table>
**Table 4-4. Safety Rules (continued)**

<table>
<thead>
<tr>
<th>Rule</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEVER give verbal orders for important operations or report such operations verbally with no record.</td>
<td>ALWAYS accompany orders for important operations with a written memorandum. Use a log book to record every important fact or unusual occurrence.</td>
</tr>
<tr>
<td>NEVER light a fire in a boiler without checking all valves.</td>
<td>ALWAYS be sure blowdown valves are closed and proper vents, water column valves and pressure gauge cocks are open.</td>
</tr>
<tr>
<td>NEVER open a valve under pressure quickly. The sudden change in pressure or resulting water hammer may cause piping failure.</td>
<td>ALWAYS use the bypass if one is provided. Crack the equalization. Then open it slowly.</td>
</tr>
<tr>
<td>NEVER cut a boiler in on the line unless pressure is within a few pounds of header pressure. Sudden stressing of a boiler under pressure is dangerous.</td>
<td>ALWAYS watch the steam gauge closely and be prepared to cut the boiler in opening the stop valve only when the pressures are nearly equal.</td>
</tr>
<tr>
<td>NEVER bring a boiler up to pressure without trying the safety valve.</td>
<td>ALWAYS lift the valve from its seat by the and lever when the pressure reaches about three-quarters of popping pressure.</td>
</tr>
<tr>
<td>NEVER take it for granted that the safety valves are in proper condition.</td>
<td>ALWAYS raise the valve from its seat with the lifting lever periodically while the boiler is under pressure. Test by raising to popping pressure at least once per year.</td>
</tr>
<tr>
<td>NEVER increase the setting of a safety valve without authority or replace with valve of higher setting.</td>
<td>ALWAYS consult an authorized boiler inspector and accept his or her recommendations before increasing the safety valve pressure setting.</td>
</tr>
<tr>
<td>NEVER tighten a nut, bolt or pipe thread under steam or air pressure.</td>
<td>ALWAYS play safe on this rule. The one that is going to break does not have a special warning sign.</td>
</tr>
<tr>
<td>NEVER strike any object under steam or air pressure.</td>
<td>ALWAYS play safe on this rule.</td>
</tr>
<tr>
<td>NEVER allow unauthorized persons to tamper with any steam plant equipment.</td>
<td>ALWAYS keep out loiterers and place plant operation in the hands of proper persons.</td>
</tr>
<tr>
<td>NEVER allow anyone to enter a boiler without taking the proper precautions</td>
<td>ALWAYS observe the OSHA Lock Out, Tag Out Procedures. ALWAYS put a sign &quot;Worker Inside&quot; on a boiler at the point where the person enters. Lock all valves closed that might endanger the person if they were opened accidentally. Station a person outside for emergencies.</td>
</tr>
<tr>
<td>NEVER allow major repairs to a boiler without authorization.</td>
<td>ALWAYS consult an authorized boiler inspector before proceeding with boiler repairs.</td>
</tr>
</tbody>
</table>
Table 4-4. Safety Rules (continued)

| NEVER attempt to light a burner without venting The furnace until clear. | ALWAYS allow draft to clear furnace of gas and dust for prescribed purge period. Change draft conditions slowly. See WARNING on page 4-38. |
| NEVER fail to report unusual behavior of a boiler Or other equipment. It may be a warning of danger. | ALWAYS consult someone in authority. |

WARNING

Do not allow fuel to accumulate in the boiler furnace. If fuel is allowed to enter the furnace for longer than a few seconds without igniting, an explosive mixture can result. It is recommended that the trial for pilot be limited to 10 seconds and the attempt to light the main burner be limited to 5 seconds. Do not exceed the normal lightoff time specified. Close the manual fuel shutoff valves if the flame is not burning at the end of the specified time.

IMPORTANT

The most important requirement of a steam and hot water boiler is that it shall be safe in so far as danger from explosion.

NOTE

If the energy in a large shell boiler under pressure is considered, the thought of the destruction possible in the case of an explosion is appalling. It is estimated that:

- There is sufficient energy stored in a plain cylinder boiler under 100 pounds steam pressure to project it, in case of an explosion, to a height of 3-1/2 miles.
- A locomotive boiler at 125 pounds pressure, from 1/2 to 1/3 of a mile.
- A 60 horsepower HRT under 75 pounds pressure, somewhat over a mile.

A cubic foot of heated water under a pressure of from 60 to 70 pounds per square inch has about the same energy as one pound of gun powder.
Section V
Startup, Adjustment and Operating Procedures

5-1. Introduction

York-Shipley Global Boilers are all fire tested before shipment. The purpose of the fire test is to check all components for proper operation, etc., and to aid in field startup. Because job site conditions are different than factory test conditions, fire test readings can only be used as a guide.

5-2. Initial Line Up Check List

These steps are common steps that should be performed on each boiler for initial start, regardless of the site conditions. These steps do not represent all that are required, as each boiler may be equipped with special order items, i.e., draft control.

1) Check all piping for completeness and correctness.
2) Remove flame safeguard control. Turn on power and check voltage characteristics.
3) Fill feedwater tank with water.
4) Open feedwater supply and discharge valves.
5) Purge and prime feedwater pump.
6) Jog motor starters and check all motors for proper rotation.
7) On steam boilers, make sure:
   • tri-cocks are CLOSED, and
   • gauge glass cocks and steam pressure gauge cocks are OPEN.
8) Close all blowdown and drain valves.
9) Open boiler feedwater valves.
10) Fill boiler with water to proper level.
11) Install required gauges, manometers and meters.
12) When firing on oil prime oil pump, start oil supply system and set external relief valve, if so equipped.
13) When firing on gas purge pilot and main gas train.
14) Install Flame Safeguard control and test meter. Reset LWCO’s.
15) Check settings of safety and operating controls. Re-adjust if necessary.

5-3. Boil Out Prior to Initial Startup
(Suggested Procedure)

The internal surfaces of a newly installed boiler will have oil, grease or other protective coating used in manufacturing. Such coatings must be removed since they lower the heat transfer rate and could lead to overheating of a tube and reduce unit operating efficiency. However, before boiling out procedures may begin, the burner should be ready for firing. The operator must be familiar with the procedure outlined in this operating manual.

Your water consultant or water treating company should be able to recommend a cleaning or boil out procedure. In following is a recommended procedure by the American Boiler Manufacturers Association for boiler boil out.

Suggested Boil Out Procedure:

1) Trisodium phosphate and caustic soda are the suggested chemicals for cleaning of newly installed boilers. The quantities will vary according to conditions, but an amount of one pound of each chemical per 50 gallons of water is suggested.

2) When dissolving chemicals, the following should be observed:

   a. Use of suitable face mask, goggles, protective gloves and garments is required when handling or mixing caustic chemicals.

   b. **CAUTION**
      - Do not permit the dry chemical or solution to come in contact with skin or clothing.

   c. Always follow the safety precautions on the container’s labeling.

   d. Warm (80 to 100° F) water should be put into a suitable container.

   e. Slowly introduce the dry chemical into the water, stirring at all times until the chemical is completely dissolved.

   f. The chemical must be added slowly and in small amounts to prevent excessive heat and turbulence.

3) Before introducing the solution into the boiler, an overflow pipe should be attached to one of the top boiler openings and routed to a safe point of discharge.

   **WARNING**
   - Boiling out under pressure is not recommended. If the unit must be boiled out under pressure, competent assistance must be provided.

4) Water relief valves and steam safety valves must be removed before adding the boil out solution so that neither the solution nor surface contaminants will settle upon the valve seats. Use care in removing and reinstalling the valves.

5) All valves in the piping to or from the system must be closed to prevent the boil out solution from getting into the system.
6) Gauge glasses must be protected from contact with the boil out chemicals during procedure.

7) Fill pressure vessel with clean water until top of the tubes in the boiler are covered. Add cleaning solution and then fill to the top of pressure vessel. The temperature of the water used in this initial fill should be at ambient temperature and softened.

8) After filling, the boiler should be fired intermittently at a low rate sufficient to hold solution just at the boiling point. Boil the water for at least five hours. Do not produce steam pressure.

9) After the five hour boil, begin to add a small amount of fresh water to create a slight overflow to carry off surface impurities. Continue boil and overflow until water clears. When water clears, shut burner off.

10) Let the boiler cool to 120° F or less, then drain using caution that the water is discharged with safety.

11) Remove handhole covers and/or wash out opening and wash the waterside surfaces thoroughly using a high pressure water stream.

12) Inspect surfaces and if not clean, repeat boil out.

13) After boil out, close all openings and reinstall safety or relief valves, gauge glasses and other components. Fill the boiler with ambient treated water and fire unit at low fire until water temperature of at least 180° F is reached to drive off any dissolved gases.

14) Boiler is now ready for operation.

**CAUTION**

If boiler is not to be operated within twenty-four hours see procedures for boiler lay-up.

### 5-4. Initial Startup Check List

**WARNING**

Only qualified boiler-burner service personnel should attempt to start-up, adjust or repair the unit. Close the manual fuel valve(s) and properly ventilate the unit before making any repairs.

On dual fuel equipped burners, start and adjust the boiler on oil first. Then, match gas to the air settings used for oil.

1) Set fuel select switch to OIL.

2) Turn on operating switch and observe for proper operation during purge. Check settings of low and high fire end switches (if provided).

3) Establish pilot and place RUN TEST switch in Test position. Adjust as needed for a strong steady pilot. Refer to Fire Test Report as a guide.

4) Cycle unit on PILOT ONLY several times to make sure pilot is adjusted properly.
5) Light burner on oil and hold on low fire until steam comes out of steam pressure gauge test cock.

6) While boiler is warming up, adjust burner for clean, stable, efficient combustion. (Refer to Fire Test Report). Record all pressures and combustion readings for reference.

7) When boiler is up to minimum steam pressure, allow burner to go to high fire.

8) Adjust high fire for clean, stable efficient combustion.

9) Operate boiler between low and high fire several times, checking for smooth clean transition.

10) Adjust linkage as required to get clean, stable efficient combustion during all boiler firing rates.

11) Check alignment and tightness of all belts and pulleys. Tighten all linkage.

12) Check all controls to make sure they function as designed and are set properly.

Common switches checked are:
• Blower Air Switch,
• Cold Oil Safety Switch,
• Oil Pressure Switch,
• Low Water Cut Off’s,
• Compressor Air Switch,
• Flame Detector, and
• All limits, interlocks and operating controls.

13) Record all pressures, combustion readings, etc. for startup records.

14) Remove gauges and manometers that were installed for testing.

15) Tighten all flare fittings, unions, etc.

16) Check piping for leaks.

17) Tighten rear door and front and rear cover plates.

5-5. Gas Startup

1) Set fuel selector switch to GAS.

2) Close manual shutoff valve closest to butterfly valve.

3) Open manual shutoff valve at entrance to gas train.

4) Reset low gas pressure switch.
5) Cycle burner and observe operation of gas valves. Verify the gas valves remain closed until the proper times.

6) Open manual shutoff valve closest to modulating butterfly valve.

7) Reset flame safeguard control and high gas pressure switch.

8) Cycle burner and establish main flame. (Hold burner on low fire if not equipped with a low fire hold switch).

9) Adjust gas pressure regulator to required outlet gas pressure. (Refer to Fire Test Report located in boiler panel box).

10) Take burner to high fire, adjusting gas pressure regulator outlet pressure as required. (Make sure boiler has reached steaming point.).

11) When burner reaches high fire, adjust gas pressure regulator outlet pressure to that required, as shown on Fire Test Report.

12) Take combustion readings.

13) Return burner to low fire take combustion readings.

14) Adjust linkage to gas butterfly valve to obtain proper combustion at low fire through range to high fire.

15) Check gas consumption against burner rating. (See Fire Test Report on data plant on boiler.

**WARNING**

Do not over fire.

17) Adjust gas butterfly valve and recalculate firing rate until proper capacity is achieved.

18) Tighten all linkages.

19) Check all controls to make sure they function as designed and are set correctly.

Common switches check are:
- Blower Air Switch,
- Low Water Cut Off’s,
- Gas Pressure Switches,
- Flame Detector, and
- All limits, interlocks and operating controls.

20) Record all pressures, combustion readings, firing low and high, etc., for startup records.

21) Remove all gauges and manometers that were installed for testing and set up.

22) Tighten all flare fittings, unions, etc.

23) Check piping for leaks.

24) Tighten rear door, front and rear cover plates.

25) Cycle burner several times to ensure proper operation.
26) Instruct operating and maintenance personnel in proper operations and maintenance of equipment.

5-6. Normal Operation

The role of the operator is primarily one of surveillance during normal boiler operations. The following items should be checked during the rounds:

1) Fuel pressures
2) Piping integrity feedwater and fuel
3) Proper air seals on all boiler doors
4) General cleanliness
5) Unobstructed intake dampers
6) Water level.

5-7. Field Linkage Adjustment

All linkage adjustments should be made from the low fire position.

1) Determine what adjustments must be made based on fuel adjustment (and see Fire Test Report).
2) Put burner in low fire position.
3) If low fire readings are correct, note them and check that set screws and linkages are tight.
4) Make required adjustments to rods and arms.
5) Tighten rods and arms,
6) Check to make sure settings are correct for low fire.
7) Run burner.
8) If more adjustments are needed, repeat above steps.

5-8. Combustion Testing

The purpose for combustion testing is to ensure that the package boiler is operating at its highest efficiency. Maintaining a boiler operating at its top efficiency helps increase the life of the boiler, reduce the potential unsafe operating conditions, increase the customer's fuel savings and reduce the stack emissions to the environment.
5-9. Oil Fired Testing

The primary enemy of the oil fired boiler is smoking and sooting. Smoke color and opacity and CO2 are the primary method of determining the combustion efficiency of the boiler.

a. **Smoke Testing**

Smoke testing is commonly performed by drawing a known volume of boiler flue gas through a filter paper and examining the particulates that remain. The darker the residue of particulates on the filter paper, the higher the soot value and the lower the boiler efficiency. The sample filter paper is compared to the reference smoke chart and assigned a number value. The number value references a soot condition of the boiler. Table 5-1 represents a typical smoke scale chart. The result of excessive smoking is the buildup of soot. Soot deposits on the heating areas of the boiler. Soot insulates these surfaces and results in the lowering of absorption of heat in the water side of the boiler. The insulating effect also drives up the flue gas temperatures. A 1/8 inch thick soot layer may increase fuel consumption by as high as 9% (experimentally derived). Figure 5-1 shows the effects of soot buildup on the typical boiler.

**Table 5-1. Effect of Smoke on Burner Performance**

<table>
<thead>
<tr>
<th>Bacharach Smoke Scale No.</th>
<th>Rating</th>
<th>Sooting Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Excellent</td>
<td>Extremely light if at all</td>
</tr>
<tr>
<td>2</td>
<td>Good</td>
<td>Slight sooting which will not increase stack temperature appreciably.</td>
</tr>
<tr>
<td>3</td>
<td>Fair</td>
<td>May be some sooting but will rarely require cleaning more than once a year.</td>
</tr>
<tr>
<td>4</td>
<td>Poor</td>
<td>Borderline condition. Some units will require cleaning more than once a year.</td>
</tr>
<tr>
<td>5</td>
<td>Very Poor</td>
<td>Soot rapidly and heavily</td>
</tr>
</tbody>
</table>
There are many factors that affect the flue gas smoke levels. The following is a list of typical items.

1. **Insufficient Overdraft**

The ratio of fuel-to-air is a critical parameter in the operation of a boiler. Too low of an air flow will result in unburnt fuel atoms in the flue gas. This condition contributes to smoking.

2. **Non-uniform Air-Fuel Distribution**

Any factor which results in delivery of more fuel or air to one part of the flame and less to some other part will result in excessive smoke. This condition results in a distorted flame shape or sparks or streaks in the flame. Some typical causes of this are worn or clogged nozzle ports, insufficient atomization air/steam, burnt or distorted turbulator blades. The non-uniform distribution of fuel oil results in the fuel in some areas not being fully atomized. Complete combustion is not achieved and smoking results.

3. **Nozzle Spray Pattern**

It is necessary that the flame shape produced by the combination of nozzle type and air pattern by properly proportioned to the combustion chamber shape. Improper shape will result in the combustion zone temperature required for ignition being higher than designed for in the burner.
4. **Firing Periods**

A boiler that is constantly cycled will have a higher probability of soot buildup compared to one which is left at a steady firing rate. The cycling boiler will not be allowed to reach and maintain an even combustion temperature. The cooler regions in the boiler will exhibit excessive soot buildup and tend to further promote incomplete combustion. Figure 5-2 shows the effects of firing period changes on the boiler efficiency.

![Figure 5-2. Burner Operation vs. Efficiency](image)

5. **Startup and Shutdown**

The starting and shutdown periods when the boiler is in transition will result in some smoking as a result of excess fuel that is being sent to the boiler when ignition is not complete. This condition occurs during both startup and shutdown. Shutdowns create an underfire air condition when the blower stops and the only source of airflow is the natural draft of the flue and chimney. Fuel is still being injected into the combustion chamber as a result of the fuel pressure bled down in the supply lines to the burner.

6. **Flame Impingement**

Flame impingement on any cool surface will result in smoke, the flame is chilled at the point of contact and further combustion ceases at that point. The most common cause of flame impingement are physical and can be easily corrected with burner adjustment.
b. **Carbon Dioxide (CO\textsubscript{2}) Testing**

The testing of CO\textsubscript{2} in the flue gas is a direct indication of the combustion quality occurring in the boiler. The physical laws of nature dictate the by-products of combustion and the initial contents of the combustion air. Through the use of known chemical procedures the contents of the gases in the flue gas can be measured. The measuring devices can be chemical or electronic. The most common method is the drager tube. The drager tube is a glass tube sealed on both ends containing a chemical compound that reacts to the presence of CO\textsubscript{2} and changes color. The greater the color change, the higher the percentage of CO\textsubscript{2} in the flue gas.

Combustion air at sea level contains 80% N\textsubscript{2} and 20% O\textsubscript{2} with the introduction of fuel into the combustion air and firing of the mix various by-products result. One of these is CO\textsubscript{2}. The desired level of CO\textsubscript{2} in the flue gas is 8 to 10% gas fired. Readings below this value are indications that an out of balance condition exists. The following reasons can cause a low reading:

- high draft,
- excess combustion air,
- firebox problems,
- air leakage,
- poor fuel atomization, and
- low fuel pressure.

These items are just a small listing of the potential problems that could exist. Any one of these or a combination of all problems, could cause low readings.

c. **Stack Temperature**

The stack temperature of an operating boiler is one of the best general indicators of boiler firing conditions. Stack temperature in itself is not a definite indication of any one trouble, but when used in conjunction with the other testing devices available it is a very useful indicator and troubleshooter. The exact values that should be observed in the stack of the package boiler are directly related to the boiler power rating and stack conditions.

d. **Draft Gauge**

A draft gauge is used to determine if the amount of combustion gas available is sufficient to support the firing rate required for the horsepower boiler being tested. The intensity of draft determines the rate at which combustion gases pass through the boiler.

Excessive draft can increase the stack temperature and reduce the percent of CO\textsubscript{2} in the flue gas. Insufficient draft makes it impossible to adjust the burner for the highest efficiency because maximum efficiency requires the proper amount of air mixing with the correct amount of fuel in the burner. There are two types of draft that need to be considered in the overfire air draft and flue draft. Proper overfire draft readings indicate that sufficient quantities of air are being
brought to the combustion chamber to support combustion. This value is based on the fuel type and the burner capacity.

The flue draft is a measure of the volume of gases passing through the boiler to ensure that the combustion pressure remains under slightly negative pressure conditions. Common values are between 0.04 and 0.06 inches water vacuum. Maintaining these draft values will promote proper overfire air flow to the burner and continue to keep boiler efficiency at acceptable levels.

5-10. Gas-Fired Testing

The testing of gas-fired boilers is essentially the same as that done on an oil-fired unit. Natural gas in an ash free combustion fuel. Therefore, testing must be done for the presence of Carbon Monoxide (CO). CO is measured in the same way as CO$_2$ with the exception of the type of drager tube being used. The contents of the drager tube for CO is yellow and changes to a brown color in the presence of the gas. The length of brown chemical is compared to a reference chart and a CO value is determined. According to gas industry standards CO-free combustion is defined as that which produces less than 0.04% CO in the flue gas.

<table>
<thead>
<tr>
<th>DANGER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide levels in excess of 200 parts per million are considered unsafe. Burner adjustment must be accomplished to reduce CO reading at or below this level.</td>
</tr>
</tbody>
</table>

The CO$_2$ values in a gas-fired boiler are determined by the type and pressure of the natural gas supplied to the burner.

The CO$_2$ values in the gas-fired boilers are critical numbers for determining the proper amount of excess air in the boiler. The type of fuel gas used also requires different values for CO$_2$ in the flue gas.

5-11. Combustion Efficiency

Gas-fired units rely on two parameters to compute boiler efficiency. The two parameters are CO$_2$ and flue gas temperature. The CO$_2$ value is a measure of combustion quality and the stack temperature represents thermal efficiency. The lower the CO$_2$ value, the poorer the combustion process. The higher the flue gas temperature, the more heat to the chimney and a lower thermal efficiency.

5-12. Routine Boiler Operations

The safe and efficient operation of a boiler is largely dependent on the boiler operator. While exact duties vary from installation to installation, there are specific functions that must be
performed to ensure boiler and support equipment integrity as well as the safety of the facility and personnel.

Operator duties typically consist of routine, periodic inspections and minor preventive maintenance functions while the boiler is in operation. Some of these functions are performed daily others are inspections and boiler up-keep items performed weekly, monthly, semi-annually and even annually.

Operator duties during boiler startup and shutdown differ greatly from the on-line duties. Although routine inspections are performed during these periods, most of the operator's job involves starting, stopping and adjusting equipment and operating parameters.

The following describes recommended operator functions during on-line operation, as well as, during startup and shutdown. By following the recommendations the operator can help ensure maximum boiler availability, capability and longevity.

5-13. Boiler Startup

A successful startup requires the proper preparation and startup of boiler support equipment and systems. While these systems and equipment are designed specific to each boiler installation, they all serve similar functions and must operate properly to support the needs of the boiler.

5-14. Boiler Support Systems Startup

Typical package boiler support systems and equipment include:

- Water supply systems,
- Boiler feedwater treatment systems,
- Boiler chemical treatment systems,
- Fuel supply systems,
- Compressed air systems,
- Boiler blowdown systems,
- Steam distribution systems, and
- Boiler equipment electrical supply systems.
SECTION IV - PRINCIPLES OF OPERATION, STARTUP AND SAFETY

a) Water Supply Systems

Many package boiler installations use a connection to a municipal water system as a makeup supply. Others use well water pumped directly into boiler supply piping or into a storage tank. When a storage tank is used, it usually contains condensed steam from steam distribution system return piping and city or well water as a makeup source. Boiler makeup water is pumped from the storage tank to the boiler.

In preparing for startup, the operator must ensure an adequate supply of water is available to fill the boiler initially, as well as makeup to support continuous boiler operation. Typical startup check include:

- proper valve alignment to boiler;
- sufficient tank level (when so equipped);
- storage tank makeup supply proper valve position alignment;
- boiler feed pumps ready for service
  - pump(s) completely assembled,
  - proper valve alignment,
  - proper lubrication levels, and
  - pump motor electrical supply energized.

b) Boiler Feedwater Treatment Systems

Feedwater treatment systems and components are designed specific to each boiler installation. Since they treat the water prior to admission to the boiler they are often called "pretreatment" systems. Pretreatment systems can include any, all or any combination of the following:

- water softeners,
- deaerators,
- filters, and
- chemical injection systems.

The purpose of installing pretreatment systems is to protect boiler components by providing water with specific properties. Therefore, the pretreatment system must be placed in service prior to startup in preparation for filling the boiler. Pretreatment system startup duties include:

(1) Water Softener

- regenerated resin (or resin not exhausted),
- regeneration system ready for service,
- proper valve alignment,
- softener rinse to water prior to admitting softener product water to the boiler.

Feedwater softeners are placed in service to treat the continuous flow of makeup water needed to satisfy boiler demand. Softener startup duties are actually the steps necessary to prepare the softener for service once feedwater is needed.
(2) Deaerator

Feedwater flow must be established through the deaerator before admitting steam. Otherwise, overheating will take place. With this in mind, and the fact that in some installations no steam source is available until the boiler is on-line, we can see that it may not be possible to deaerate the initial boiler fill water. However, the feedwater flow will still be routed through the deaerator in route to the boiler.

Each deaerator application has specific requirements for startup and operation. The following sequential steps are used to place a typical deaerator in service:

- Establish water flow into the deaerator. (Water softeners are placed in service before the deaerator when system is so equipped);
- Establish deaerator level; and
- Start the boiler feedwater pump to provide flow to the boiler.
- Once the boiler is on-line and steam is available:
  - Open the deaerator vent to the atmosphere.
  - Open the deaerator steam supply valve to pressurize the deaerator.
  - Ensure that the deaerator remains pressurized with the vent valve(s) open.

(3) Filters

Filters and/or strainers are included in some boiler feedwater supply systems. The duplex strainer is often used because of its flexibility. A duplex strainer is actually two strainers in one housing. The handle on top of the housing is used to place one strainer in service while isolating the other with a single motion. Regardless of the type of filter or strainer in the feedwater system, certain general steps can be used to place the unit in service.

Prior to starting the system, the following filter/strainer parameters should be verified:
- filter and/or strainer assembly completely assembled; and
- valves properly aligned
  - inlet and outlet open,
  - bypass valves closed, and
  - drain (blowdown) valve closed.

Some filter/strainer installations have pressure gauges installed in the inlet and outlet piping. When in service, the difference in these two pressures indicate the restriction to flow caused by the filters. An abnormally high pressure difference means that the filter/strainer is restricting flow and is probably dirty or damaged. Once flow through the filter/strainer is established, these pressures should be checked. A dirty filter/strainer should be cleaned as soon as possible. In the case of the duplex filter, the alternate filter can be placed in service while the first side is cleaned. Single filter installations may require that a by-pass valve be opened while the filter/strainer is cleaned.
(4) Boiler Feedwater Chemical Injection Systems

Some boiler feedwater systems include chemical injection equipment. This equipment is usually a one shot feeder or a mixing tank-pump assembly. Regardless of the type of feed system, boiler feedwater chemical injection is important during initial boiler filling. Most installations have vendors operate these systems. However, the boiler operator is often responsible for maintaining the system.

General steps for shot feeder startup include:

1). Shot Feeder
   a. Isolate the shot feeder from the feedwater system by closing the inlet and outlet valves.
   b. Drain the shot feeder by opening the drain valve and vent valve.
   c. Once completely drained, close the drain valve.
   d. Charge the feeder (through the feed funnel) with the proper amount of dry chemical.
   e. Close the vent valve and chemical inlet valve.
   f. Open the feeder inlet and outlet valves to complete the operation.

2). Mixing Tank-Pump Assembly
   The chemical injection system, whether a shot feeder or mixing tank assembly, should be started immediately after starting the boiler feedwater system. It is very important that the water used to initially fill a boiler after an outage be treated.

   The steps for starting a typical mixing tank chemical injection system include:
   a. Ensure mixture in tank has the proper chemical strength and level.
   b. The mixing tank mixer must be in operation any time there is fluid in the tank.
   c. Open chemical injection pump
      - suction valve
      - discharge valve
      - feedwater system isolation valve.
   d. Start the chemical injection pump.
   e. Verify that the pump discharge pressure is normal.
   f. Periodically check the level in the mixing tank to verify that the level is being reduced. This indicates that the chemical solution is being pumped into the boiler or boiler feedwater.

Chemical injection mixing tank-pump systems use one of two methods of controlling the amount of chemical injected into the boiler feedwater:
   • controlling the strength of the mixture in the tank, and
   • controlling the rate of injection.
The strength of the solution in the mixing tank is determined by the amount of chemical (wet or dry) that is dissolved in a specific amount of water.

Water treatment contractors (or plant chemists) are usually responsible for specifying the strength of the mixture. The strength is calculated to meet the needs of specific boiler conditions and specific water characteristics. The mixture is stated as a specific weight of chemical to be mixed with a specific amount of water in the mixing tank. Proper treatment, and ultimately the integrity of the boiler metals, is largely dependent on the accuracy of the mixture.

The rate of chemical injection into the feedwater is controlled by one of two methods:
- pump stroke, and
- pump discharge flow.

Most chemical injection pumps are positive displacement, piston type pumps. Some models have an adjustment mechanism that regulates the frequency of the pump stroke. This, ultimately, controls the amount of solution the pump delivers to the feedwater.

Another method of controlling the amount of solution injected into the feedwater is, simply, a control valve in the pump discharge piping. The amount of solution flowing through the valve and into the feedwater piping is controlled by opening or closing (throttling) the valve.

d) Fuel Supply Systems

Package boiler fuel supply systems, like other support systems, vary in design to meet the needs of the specific boiler installation. Some boilers burn gas while other burn fuel oil.

(1) Gas
Most boiler gas supply systems are very simple in design and operation. The typical system consists mainly of valves used to isolate the boiler supply piping from the main piping system, a pressure control valve and isolation valves for gas metering equipment. Some systems have moisture traps that collect condensation to prevent it from affecting burner operation.

Some boiler facility safety procedures require that the gas be isolated from the boiler during boiler outages. Many times this is accomplished by closing a single valve.

**DANGER**
After work is done that requires opening the fuel gas piping system, or on initial operation, the piping system must be purged of air before lightoff is attempted.

Startup of most gas systems involves a simple verification of proper valve alignment. However, if the gas piping has been isolated, it must be vented to remove air from the pipes. This is accomplished by first opening the gas supply valve and then opening an atmospheric vent valve. The vent valve remains open until gas only is emitted from the vent. NO SMOKING DURING THIS PROCEDURE. Most burner control systems monitor the fuel supply and will not allow the burner(s) to operate unless a minimum fuel supply pressure is detected.

(2) Fuel Oil Systems
Boiler fuel oil supply systems are much more sophisticated than gas systems. A boiler fuel oil supply system is shown in Figure 5-6. The system shown is typical for fairly large boiler installations.

The design and components included in a specific system are dependent on the grade of oil used and specific burner requirements. As can be seen in Figure 5-6, fuel is supplied to the burner(s) by a pump or pumps that take suction from a "day tank" usually located in or very near the boiler building. The purpose of the day tank is to provide enough oil storage to support boiler operation for a specific time period, usually 24 to 48 hours. Day tank makeup is provided from a larger storage tank used to receive and store oil deliveries. Some smaller installations have no large storage tanks. When this is the case, deliveries are made to the day tank.

Oil is pumped from the large storage tank to the day tank to maintain the day tank level. This is often part of the operator's job and may be done on a routine schedule (daily, every two days, etc.).

A strainer is provided between the day tank and the fuel oil pumps. The strainers remove any particles that could damage the oil pump(s) or plugs passages in the burner tip. Oil strainer design is very similar to the strainers used in feedwater systems.

![Figure 5-6. Simplified Fuel Oil Supply System](image-url)
The fuel oil pumps are usually positive displacement type pumps (previously discussed). Positive displacement pumps will build enough pressure to damage downstream components, as well as their own components if the discharge flow path becomes blocked (closed discharge valve, etc.). Most pump installations have pump recirculation piping with an internal or external pressure relief valve. The relief valve opens when excessive pump discharge pressure is sensed. This reduces the pressure by providing a flow path from the pump discharge to the suction side of the pump.

The system (oil pressure to the burner) is controlled by a modulating control valve. This valve is often a diaphragm operated valve. The pressure control valve regulates pressure by throttling oil from the oil pump discharge header back to the day tank. The valve will close to raise burner oil supply pressure and open to lower pressure.

The final element in the fuel oil supply system is the fuel oil meter. The meter measures the amount of fuel delivered to the burner(s). Operators are sometimes required to record fuel oil metering readings for accounting purposes.

Boilers burning "heavy" oil (such as #6 oil) require that the oil be heated by a fuel oil heater. The heating acts to thin the very thick oil by lowering its viscosity to allow it to be pumped and burnt. Fuel oil heaters sometimes use steam to heat the oil. As the oil flows through tubes in the heat exchanger, steam is admitted to the outside of the tubes to heat the oil. Other types of heaters use electric heating coils in a heat exchanger to heat the oil (much like an electric hot water tank).

Boilers burning #2 oil do not require fuel oil heaters since this grade of oil is "thin" and easily pumped.

The fuel oil supply system discussed up to now is used in fairly large boiler plants. While the fuel storage and day tanks are used in smaller installations, the delivery system is sometimes quite different.

Oil enters the oil delivery system from the day tank and passes through a strainer that removes particles from the oil. The fuel oil pump takes suction from the strainer and discharges through the pressure control valve to the burner nozzle. The pressure control valve regulates pressure to the burner nozzle by relieving excess pressure from the pump discharge and pump shaft seal chamber back to the fuel oil strainer.

Fuel oil system startup is dependent on the specific system and components. General startup steps include:

a. Prestart System Status Checks
   • Day tank level must be adequate to start boiler and support combustion until tank can be refilled.
   • System valves must be properly aligned from the day tank to the burner control components.
   • Electrical power must be available to all pumps, heaters and controls.
• Compressed air must be available to operate any pneumatically operated valves, etc..
• Pumps, piping, tanks, valves and other in-line components must be completely assembled.
• Indications of oil leaks (from previous operation) must be investigated and repairs made.

b. Start the pump
c. Check the system for leaks
d. Place the oil heater in service (if so equipped).

e) Compressed Air System Startup

The York-Shipley Global boiler systems that used compressed air are supplied prior to startup by the boilers own dedicated compressor. If the compressed air system is completely shutdown, the steps for startup include:

1. Drain all moisture from the compressed air piping, then close drain valves.
2. Compressed air system valves should be properly positioned to provide flow to the boiler system air operated equipment.
3. Air compressor integrity should be verified before starting.
   • All components completely assembled
   • Air inlet filter clean and undamaged
   • Lubrication levels normal
   • Belts, hoses and other accessories installed and in good condition
   • Electricity available to the compressor motor.
4. Start the compressor
5. Operating checks and duties:
   • Check air system pressure.
   • Check for unusual noises and odors.
   • Check lubrication levels.
   • Check for belt looseness (flopping).
   • Check for air leaks.
   • Blowdown (drain) each compressed air piping drain valve available.

f) Boiler Blowdown System

The boiler blowdown system must be ready for operation prior to firing the boiler. This is particularly important after a long outage when more than the normal amount of blowdown is required to clean up the boiler water.

Boiler blowdown system startup steps include:
1. All components assembled.
2. Valves properly positioned to align boiler blowdown to the blowdown tank (when equipped with tank), or to the blowdown outlet.

3. Tank vent valve open (when equipped with tank).

g) Steam Distribution System

The steam distribution system does not start operation until the boiler starts producing steam. However, the system should be prepared for service prior to admitting steam. These steam can be performed as the operator walks down the system and checks the following items:

1. All piping and components properly assembled.

2. All steam traps drained and valves properly positioned for operation.

3. All system valves properly positioned to route steam to the desired equipment.

4. All system drain valves should be opened and remain open until all moisture is drained. Once a drain flow has stopped the drain valves remain "cracked" open slightly to drain moisture from steam condensing as the piping is initially heated and pressurized.

h) Boiler Electrical Supply System

Electricity must be available to operate boiler and boiler support components (pumps, valves, compressors, heaters, controls, etc.). During short outages this is usually not a problem since power may not be shut off. However, during extended outages and/or outages where a lot of maintenance is performed, some electrical circuits are usually isolated.

Whether the boiler operator or facility maintenance personnel (electrician) are responsible for the electrical system, power availability should be verified prior to initiating the boiler startup.

The basic procedure involves simply checking the electrical supply breakers position for each piece of equipment. If an electrical breaker is found in the "open" (off) position, an investigation should be conducted before closing (turning on) the breaker. There is always a reason for a breaker to be turned "off". The operator and/or electrician must verify that the equipment and/or circuit isolated by the breaker is ready for service before closing the breaker to restore power.

Breakers trip to protect the circuit, equipment and personnel from the results of an electrical system fault or overload.

**IMPORTANT**

Never reset (turn on) a tripped breaker without correcting the cause for the trip.

5-15. Boiler Startup Steps

Once the boiler support systems are in operation, the boiler itself can be started. The following startup steps provide a general method of starting the York-Shipley Global Model SPH and SPL
boilers. Since each boiler application differs somewhat, the exact procedure will differ for each boiler application.

1. Place the Main Burner Power Disconnect Switch in the "ON" position to provide power to the burner control system.

2. Place the Fuel Valve Switch in the "ON" position and the Emergency Switch in the "OFF" position to allow the fuel valve to open when the controls signal it to do so.

3. Start the boiler feedwater and chemical reinjection system and fill the boiler to the prescribed level.

4. Once the boiler is filled, reset the Low Water Cut-Off Switch to rest the low level interlocks.

5. Start the fuel oil pump blower and air compressor by turning the fuel valve switch to the "OFF" position. The pump will circulate oil to and from the fuel oil tank (day tank).

6. Verify that the fuel oil heater is full of oil then start the heater by turning "ON" the electric preheater disconnect switch.

7. Turn "ON" the Gas Pilot Valve and purge air from the line by opening the vent valve momentarily.

8. If the unit is gas-fired, charge the gas piping by opening the supply isolation valves.

9. On an oil-fired unit, verify that the oil pressure is constant at the section side of the pump, at any single setting between 10 inches Hg vacuum and 5 psi. If the pressure fluctuates, it is an indication that the oil is too hot or air is trapped in the fuel oil suction line.

10. Verify adequate air compressor discharge pressure. Low fire range requires from 5 to 10 psi and high fire requires from 15 to 20 psi.

11. Turn the Fuel Valve Switch to the "ON" position to stop the motor.

12. Start the boiler ignition sequence by turning the Emergency Switch to the "ON" position. If the burner motor does not start, the "Limit" controls should be checked to identify which control is preventing the startup. Once identified, correct the condition that is initiating the "Limit".

13. Once the burner motor starts, observe the sequence of operation. The exact sequence is shown in the individual burner control system service manual. Section 1 of this text describes the various control systems commonly used on York-Shipley Global boilers.

14. If the boiler is being started as a cold startup operation (cold water in the boiler), the burner should remain in the Low Fire mode of operation to allow the boiler to warm up slowly. Some units have manual potentiometers or low fire hold controls wired in permanently.

   Once the boiler is hot, the modulating motor can allow the burner to move into the High Fire mode of operation. One method of identifying the boiler as hot is by feeling the Low water Cut-Off pipe which is a good indication of the boiler temperature.

**NOTE**
Once the boiler is started, it will be necessary to adjust the modulating control (mounted on the low water piping) for the desired pressure at which the control system switches back to the low fire mode.
15. As the boiler builds temperature and pressure, monitor support system operation.

16. Close the drain valves in the steam distribution system piping as they warm up and pressurize.

17. Verify the operation of "Limit" controls by actually causing a limit parameter to reach its set-point and the operation of the control system.

18. Once the startup is complete and the boiler is maintaining set-point pressure, perform a walk down of the boiler and all support equipment checking for abnormal conditions.

19. Be especially watchful of the condensate system’s ability to maintain adequate feedwater to the boiler.

5-16. Boiler Failure to Start

In the event a burner should fail to start, the operator should conduct an investigation to identify the cause of the failure and take steps to correct the problem(s). The most common reasons for a burner start failure are:

- electrical system fuses burned out,
- low boiler water level,
- limit control switches failure to make-up, and
- fuel oil supply system low pressure.

Once the cause of the failure has been identified and corrected, two items may be "Reset before attempting another start:

- depress the limit or interlock RESET push-button, or
- depress the burner control system program RESET push-button.

If the burner fails to start after all obvious problems are corrected (e.g., resets performed) the operator should call the York-Shipley Global distributor for assistance.

5-17. Boiler Shutdown

The shutdown of the York-Shipley Global Series 500L consists basically of shutting down the burner. The burner is stopped by opening the blower and control operating (emergency) switch. Once the burner shutdown is initiated, the burner management system shuts off the fuel supply and purges the oil gun. The exact sequence is specific to the burner control system on the particular boiler.

Once the boiler shutdown is initiated, there are two important surveillance duties the operator performs to ensure the safety of the equipment and personnel.

1. As soon as the shutdown is initiated, the burner shutdown should be verified. This means visually checking to ensure that no flame is present and that no fuel is being fed into the boiler. Some installations have a policy of closing manual fuel supply isolation valves as soon as burner is shutdown is initiated.
2. **Ensure that a normal boiler water level is maintained until the boiler is cool.** The boiler metals store a lot of heat and remain hot enough to cause extensive damage if not cooled by the proper water level. The water makeup supply source should remain in service as well as the chemical injection system until the boiler has cooled.

Once cooled, the makeup water supply can be isolated and the boiler drained if desired.

Once the boiler is shutdown, support equipment can be removed from service. The shutdown of the systems are dependent on the length of the boiler outage, individual system design and specific installation policies. During a short outage no support equipment is shutdown. During long outages almost all support systems are shutdown.

Operator should become familiar with individual equipment and systems and plan their operation during an outage based on the reason for the outage and planned outage length.
Section VI
Service and Maintenance

6-1. Periodic Service Inspections and Maintenance

The integrity of boiler components and longevity of the boiler is largely dependent on the way it is operated. During operation, specific functions can be performed to help ensure the longevity of any boiler. Some of these functions are performed while the boiler is in operation, while others require removing the boiler from service. These functions can be classified into a schedule of periodic operator duties:

A. Daily - To be performed once a day while the boiler is in operation.

B. Weekly - To be performed once a week, in addition to the daily duties.

C. Monthly - To be performed once a month, in addition to the monthly and daily duties.

D. Semi-Annually - To be performed once every six months in addition to the monthly, weekly, and daily duties.

E. Annually - To be performed once a year in addition to the semi-annual, monthly, weekly, and daily duties.

NOTE
The exact duties listed in this section are specified to York-Shipley Global Series 500c. However, they are typical of the types of duties performed for many other package boiler models.

6-2. Daily Procedures

1) Blowdown boiler using rear blow-off (larger boilers have front and rear blowoff connection). Blowdown when burner is firing. Burner should shut off at low water level. Investigate and correct failure to shut off.

2) Blowdown water column to low water cut-off point.

3) Check level of oil in storage tank.

4) Check lubricating oil in compressor oil cup, (where compressor used) fill with non-detergent oil, Socony DTE Light or equivalent when required. If in doubt, order oil from York-Shipley Global.
5) Monitor stack temperature. If high, check fire side of boiler for dirt, over-firing, or improper combustion.

6) Check temperature of water supplied to unit and if below 160 degrees, preheat return to not more than 200 degrees.

7) Check oil pump suction conditions. Should not exceed 130 degrees or 5 pounds pressure.

6-3. Weekly Procedures

1) Check combustion control operation as outlined in check list section of service manual. Investigate and correct at once any failure to shut off fuel valve.

2) Check the pressure limit shutdown as outlined in the service manual checklist. During this check, observe the operation of the programming control to make sure that the operation is as described in the sequence of operation section of this manual.

3) Wipe the entire unit, particularly the operating parts, so that oil and dust do not accumulate.

4) Clean oil nozzle weekly. Do not use abrasive or metallic instruments or tools during the cleaning operation. Soak nozzle assembly in oil solvent for required time. Clean electrode insulators of any carbon deposit.

5) Replace nozzle electrode assembly in the exact position as was sent from factory.

6) If water treatment is being used, check water against checklist supplied by water treatment company.

7) Never introduce feed water treatment through the feed water pump or condensate tank. Treatment should be introduced directly into the boiler or device located on discharge side of the feed water pump.

6-4. Monthly Procedures

1) Check belt tension and adjust if required.

2) Turn down feed water pump grease cups if used.

   **NOTE**
   Every 3 months fill cups with new Standard Oil Company N. 18 Superla grease.

3) Clean feed water strainer between the pump and the condensate return tank.

4) Lift the steam safety valve or hot water safety valve by the manual lever to make sure it is operating freely.
5) Clean compressor air intake filter (where compressor used). Replace filter oil with clean oil, use compressor lubricating oil.

6) Check rear head for flue gas leaks and tighten bolts as required. Tighten bolts evenly - uneven tightening will cause leakage.

6-5. Semi-Annual Procedures

1) Cool boiler slowly to room temperature. Failure to cool boiler slowly will effect life of boiler and possible cause tubes to leak. This is important.

2) Remove gradually all the nuts or pins around the rear head flange, pry the head loose from the boiler and swing it away on the davit.

3) Using flue brush and vacuum cleaner, brush through the tubes to the front end of the boiler.

4) Soot and scale may be removed from the front end of the boiler by removing the clean-out cover located at the bottom of the front cover plate and inserting vacuum cleaner hose.

5) Check the rear head refractory and patch any cracks or sprawls with refractory cement. If refractory requires replacement a sectional assembly may be obtained from the factory through the nearest York-Shipley Global distributor.

6) Always replace the 1-1/4" ceramic fiber rope around the edge of the rear refractory with a new rope and clean off any old cement. The new rope may be held in the groove with cement.

7) Close the rear head and using a cross pattern, tighten the head nuts until sealed.

8) Clean the peep sight glass and replace.

9) Flush compressor.

10) Examine belts for signs of wear. Replace worn belts before they fail so as to prevent shutdown.

DANGER
Safety controls and safety relief valves must be operationally tested, as required but at least semi-annually in accordance with ASME Boiler and Pressure Vessel Code, Sections VI and VII.

6-6. Annual Procedures

1) Follow steps 1 through 11 listed under Semi-Annual Procedures.

2) Clean water side of boiler as follows:
   a) Drain the boiler through the blowdown valve.
b) Remove all handhole covers and the manhole cover and replace with new gaskets.

c) Wash down the inside (water side) of the boiler with a hose, making sure to get all sludge out of bottom of boiler.

d) Inspect shell and tube surfaces for signs of corrosion or scale formation. If scale is forming (to any degree) on internal surfaces, chemically treat the entire boiler. Consult water treatment personnel for correct procedure.

e) Using new gaskets, install the handhole covers and manhole covers.

f) Disconnect the piping on the discharge side of the feed water pump and inspect for scale build-up. Check stop and check valves for proper operation and replace, if necessary.

g) Fill the boiler by means of the feed water pump and reset the low water cut-off.

3) At the time of this yearly inspection and cleaning, it is recommended that the local York-Shipley Global distributor, or agent, be called in to check the condition of the equipment.

6-7. Operation Test

Typically all boilers are fire tested at York-Shipley Global's factory. An operation test data sheet is fastened to the inside of the control panel door, with the information as shown in Figure 6-1 page 6-5.

You will notice in the upper right-hand corner, the boiler data information is shown, such as serial number, boiler number, etc. This data should always be used to identify a particular unit when requesting assistance and/or information from the Factory Service Department at 693 North Hills Road, York, Pennsylvania 17402-2211 or other authorized service agencies.

CAUTION
The operation Test Data, Figure 6-1, should be re-verified periodically or when changes are made.
Figure 6-1. Operation Test
6-8. **Pre Start-Up Inspection**

A Start-Up form shown in Figures 6a-2 through Figure 6b-2 pages 6-7 through 6-10 is supplied to each respective representative for his/her Pre Start-Up Inspection as required by terms of existing contracts. The representative will forward the form to the service agency, who in turn starts the equipment and completes this form.

The form is then forwarded by the service agency to our offices in York, Pennsylvania for proper distribution and payment of start-up and service reserve moneys. According to our policy, this form must be completed in its entirety, with signatures of the service personnel, customer and/or custodian affixed.
Name of Independent Representative: ___________________________ Date: ____________

Start-Up Agency: ____________________________________________

Address: __________________________ City: ________________ State: ______ Zip: ______

Customer Name: __________________________ City: ________________ State: ______ Zip: ______

Address: __________________________ City: ________________ State: ______ Zip: ______

Location of Installation: ____________________________________________

H-Number: ___________ Unit Model Number: ____________________________

Serial Number: ___________ Type Fuel: __ Voltage/Frequency/Phase: __ / __ / __

The equipment described above has been inspected by me and the following points checked for completeness:

Yes  No

1. Has the equipment been installed in accordance with York – Shipley Global’s instructions and the requirements of the job specifications?  
   ☐  ☐  ☐
   Comments: ____________________________________________________________

2. Has the equipment and system been hydrostatically tested and thoroughly flushed out, subsequently drained and inspected, and refilled with treated water ready for boil-out?  
   ☐  ☐  ☐
   Comments: ____________________________________________________________

3. Are proper chemicals on hand for boil-out? System volume (water content) must be known. For volume of York – Shipley’s equipment, consult our installation instructions which were furnished with this equipment. In addition, has a water treatment expert been retained to ensure proper treatment?  
   ☐  ☐  ☐
   Comments: ____________________________________________________________

4. Are forced draft fans operable?  ☐  ☐
   Has alignment been checked?  ☐  ☐
   Have all parts including bearing and couplings been lubricated?  ☐  ☐
   Does the boiler room have proper ventilation to permit adequate combustion air to the burner with all boiler room doors closed?  ☐  ☐
   Comments: ____________________________________________________________

Figure 6-2a. Pre Start-Up Inspection page 1 of 4
5. Is fuel burning equipment now operable and fuel oil and/or main gas and pilot gas piping complete?  
   Has fuel oil suction line been tested by installer?  
   Has gas line been tested for leaks and pressure availability?  
   Has oil line been primed and purged?  
   Comments:  

6. Are gas and oil fuel lines clean and free of dirt, chips, weld beads, etc?  
   Has oil tank vent line been installed?  
   Comments:  

7. Are strainers provided to prevent entry of foreign materials into fuel control valves?  
8. Are gas and oil supply systems fitted with pressure and temperature regulators which will maintain constant fuel supply conditions?  
   Comments:  

9. Are circulating pumps and their regulating devices (valves, gauges, etc.) connected and operable?  
   Have pumps been aligned and checked for proper rotation?  
   Comments:  

10. Is water supply connected to boiler?  
11. Have steam lines or exit water lines been connected?  
12. Before starting circulation, the entrance to the circulating pump(s) should be protected temporarily with wire mesh screens if strainers are not installed so that gravel, welding slag, and other material will not harm the pumps.  
   Has this been accomplished?  
13. Is the breeching connected to the stack?  
   Is the stack configured to minimize pulsation?  
   Preferably, a straight up stack should be used. Otherwise, every effort should be made to limit turns in the stack.

Figure 6-2b. Pre Start-Up Inspection page 2 of 4
<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>14. Are there any items supplied by us that are obviously damaged, missing or defective?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Have you informed York – Shipley Global of such damage?</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>15. Is there ample fuel available for operation of burner and pilot?</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>What grade fuel oil is contained in the fuel oil tank?</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>Is this consistent with the burner specifications?</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>16. Do you have qualified operators for the equipment?</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>17. Have all electrical connections been made?</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>Refer to wiring diagram for details of wiring to be done. Check to insure that all limit devices mounted externally to the equipment are wired and are in operable condition.</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>What is the voltage available to the boiler?</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>18. Has lagging been installed on hot lines, particularly on heavy fuel lines, breeching, and connecting circulating lines to and from the equipment?</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>19. Full capacity load for short periods (sufficient time for fuel-air ratio adjustments) will be required for complete burner adjustment. Can this be done?</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>20. Your Equipment Instruction manual and auxiliary equipment instructions and drawings contain information concerning certain basic requirements for a new installation, and are intended to guide you in your plans for completing the installation and making it ready for initial operation. If additional advice is required, consult with York – Shipley Global.</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>21. If all of the above work is not completed prior to arrival of the start-up agency, the additional waiting time and/or travel time and associated expenses caused by the delay will be charged for at standard per diem rate in effect at time service is rendered, plus living expenses.</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>22. Based on the above, is the equipment available for start-up?</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6-2c. Pre Start-Up Inspection page 3 of 4
York – Shipley Global Pre Start-Up Inspection
Packaged Firetube Boilers

H-Number ________________

23. List below the name, address, and telephone and fax numbers of the person located at the installation who is responsible for completion of the above work so that we can communicate with him, if necessary.

Please print:

Name: __________________________________________________________________________________
Address: _______________________________________________________________________________
Telephone Number: __________________ Fax Number: __________________
Signed: __________________________
Company: _________________________
Date: ____________________________

Witnessed by York – Shipley representative or his agent
Signed: __________________________
Company: _________________________
Date: ____________________________

Thank you for your cooperation.

Please forward original to:

Power Mechanical, Inc.
York – Shipley Global
4811 Commerce Drive
Newport News, VA 23607 USA

Please forward a copy to the start-up agency.
6-9. **Instructions for Installing New Chamber Tile in Furnace Tube**

1) Before attempting to cement the chamber tile in position, lay the bricks up dry at the end of the firing tube. This will let you gauge approximately how much cement is needed on the back of the bricks and between the joints. This is also a check to determine if the bricks are proper for the size of the boiler.

2) Cement the first brick and position. Tap the bricks with a mallet to set them. Continue to build up the sides. The top brick will be the key brick and, because of the tongue and groove in the bricks, will have to be put in from the front or rear. If the fit is too tight to allow this brick to slide in, tap the bricks so they will move downward and to the outside of the firing tube. Do not make it too loose, it must be engaged in the tongue and groove. Keep one-quarter inch (1/4") to three-eighth inch (3/8") clearance on the top for expansion.

3) When 2 or more rows of liner bricks are used, stagger the brick joints.

4) Smooth out the cement at the joints and do not allow any cement to protrude above the brick surface. Do not allow any brick to be higher than the air cone refractory where they join in the firing tube.

**WARNING**

Before entering the boiler for repair or inspection observe the OSHA Lock Out Tag Out, and Confined Space Procedures
6-10. Warning for Installing Plastic Refractory

WARNING

POTENTIAL HEALTH RISKS ASSOCIATED WITH FAILURE TO UTILIZE SPECIAL PROTECTION AND SPECIAL PRECAUTIONS ASSOCIATED WITH HAZARDOUS MATERIALS

The manufactures of the refractory and gaskets, as well as other materials commonly used in boilers have issued Materials Safety Data Sheets (MSDS's) for each of their products. Many of these products contain free or crystalline silica and other products which are considered hazardous and pose a health or safety risk if handled improperly. Crystalline silica has been classified as a Class 2A Carcinogen. Many other materials including fiberglass and the by-products of metal working, also pose potential health threats under various conditions. Typical Data Sheets for materials commonly used in boilers are included in Appendix C hereto. The manufacturers of these materials will furnish updated MSDS sheets upon request which should be thoroughly reviewed prior to the cleaning, repair, maintenance or operation of boiler room equipment. These Data Sheets present detailed warnings on the hazards from materials used in the manufacture of boilers. They also present recommendations on the special precautions required to avoid health and safety risks.
**IMPORTANT**

1) Before removing the old refractory, make a note of the thickness at different positions on the boiler. If you have the thickness greater than it should be, the rear head will not enter properly.

2) Check the refractory at the tube sheet so that refractory is approximately three-eighth inch (3/8") lower than the tubes. This is done so a tube roller can be used, if necessary.

3) Be sure to have a nice blend around the firing tube so there is no obstruction.

4) It is not necessary to smooth out the refractory. It is better if it remains rough as it will dry out better.

5) Plan the job so that it can be completed without a long delay to insure proper setting and knitting.

6) After the job is finished, check the sides and top to make sure it has not sagged. If it has, a little tamping might be necessary to make it cling better around the hangers. This happens sometimes if the material is very new from the factory and is soft. If this is recognized when opening a carton, it can be broken in small pieces, and allowed to dry out to its proper consistency.

7) Do not over-tamp with hammer, watch the material knit into the material already hammered and stop hammering.

**CAUTION**

Do not allow any refractory to be subjected to boiler fire for at least 48 hours or explosive spalling could result.

**NOTE**

Do not allow refractory to cure in temperatures that are less than 40°F or refractory damage will occur.
SECTION VI - SERVICE AND MAINTENANCE

6-11. Removal and Replacement of Front Cover and Gaskets

1) Remove the nuts which fasten the front cover to the boiler, and remove the cover.

2) On boilers with optional front cover hinges, unscrew the two (2) special hinge bolts evenly until the head clears the studs on the boiler.

3) Replace all gaskets before replacing the front cover. Use a cement (such as 3M) to hold the fiberglass tape gasket in place during re-assembly. Use butt joints (no overlap) for a good seal.

4) On boilers with optional front cover hinges, swing the cover into place, then tighten the two special hinge bolts evenly until the head is back in place on the studs.

5) Coat all studs with grease or anti-seize lubricant.

6) Tighten the nuts evenly on the center firing tube.

7) Tighten the nuts evenly around the outer edge.

6-12. Internal Cleaning and Care

Manhole is provided in all boilers over 48" diameter. All boilers are provided with handholes located so that all internal parts of the boiler that come in contact with water can be cleaned and inspected. The manufacturer recommends that to insure the proper life of your boiler, the water be treated by a reputable company in the boiler water treating business.

6-13. External Care of Boiler

The construction is simple, so a specific part of the upper pass can be inspected without disassembling the complete rear head. Boiler assemblies include rear davits to swing the rear head, with tapered pins in place of screwed nuts as optional items.

Whether the bolted davit or the pinned davit is used, the procedure for cleaning or inspection remains the same.

The rear head covers are designed to be gas tight and, therefore, care must be taken when removing and replacing.

The boiler proper: This is the most costly single part of a unit and, frequently, the part most neglected. The "Fire-side" of a boiler should be cleaned periodically, since a dirty boiler is a fuel waster.

Clean boiler flues as follows:
6-14. Feed Water Treatment

York-Shipley Global recommends to all its customers and agents that reliable water treatment companies be consulted in regard to the proper treating of boiler water.

6-15. Scale Removal From Internal Parts or Boilers

The two methods available are mechanical and chemical.

1. **MECHANICAL:** Removal of scale by mechanical means is divided into two general classes, only one of which applies to the firetube product. This method involves the use of vibrators which are cleaners that vibrate the tube with a hammer like action so that the scale is jarred off.

   The cleaner consists of a small motor which can convert the energy from steam, air or water into high rotative motion. Attached to this machine is a device termed a "knocker" which, when rotated at high speed in the tube, vibrates with great force. This will only remove the scale deposits on the boiler tubes and leave the scale on the furnace tube and tube sheets, or heads. The chemical method would seem to be the best to use although there are certain dangers which should be well understood before the attempt is made.
2. **CHEMICAL:** The chemical method of cleaning the insides of packaged boilers involves the selection of a chemical (acid) which will react with the type of scale present.

**WARNING**

Muriatic acid is dangerous to use and it is strongly recommended that the greatest precautions be exercised in its use. Protective clothing, eye shields, greased face - or masked, with rubber gloves for the hands is recommended. Read all warning labels on Muriatic acid.

Most hard scales are of the calcium or magnesium type, with calcium being the most prevalent. The acid recommended for the elimination of this type scale is known as Muriatic acid.

In using this acid, the quantities needed must first be determined. By consulting the literature of the boiler on hand, the total gallons required can be determined. The literature will give the dry and wet weight of the unit. By subtracting the dry from the wet weight, the total weight of the water may be determined. Divide this figure by 8.33 lbs. per gallon to determine the total number of gallons.

Secure a sufficient quantity of Muriatic acid to mix one to three with fresh water. One quantity of acid to three of water.

After the Muriatic acid has been diluted with water on the one to three ratio, add to this solution pure sodium dichromate - one ounce to one gallon of the above solution.

Place this mixture in the boiler and fill to the top of the manhole.

Bring the boiler temperature to just below the boiling temperature and allow the boiler to remain at this temperature from eight to twelve hours.

Open the manhole and with a strong light, observe the appearance of those portions of the water side which had scale deposits prior to cleaning. After the solution has removed the scale (will fall to bottom or go into solution), it is necessary to neutralize the acid solution to prevent etching or thinning the tubes.

Add to this solution of Muriatic acid and water, soda ash in quantities of 150 to 1. For every 150 pounds of water, add one pound of soda ash, since it comes in dry form.

Bring boiler to just below the boiling point and allow the solution to remain for approximately one hour.
Secure a sample of the remaining solution in the boiler and test to see if the soda ash has neutralized the acid content. If not, add more soda ash and bring unit to boil as per the above. After the boiler water has been neutralized, drain unit and flush boiler two times with fresh water. When this is finished, make sure to add sufficient quantities of sodium sulfite to bring the sulfite content to within 25 to 50 PPM. Treat for proper pH as well as any other treatment recommended.

6-16. Cause of Tube Leaks

The boiler tubes will, on occasion, become loosened in their joints and will require repair.

Normally tubes will leak at their point of attachment to the tube sheet and this type of leakage will generally occur at the beginning of the first tube pass (the bottom of the tube sheet at the rear of the unit).

This condition may occur under the following circumstances:

- Over-firing (exceeding the rating) of the boiler.
- Thermal shocking of the unit.
- Hot firing a cold boiler.
- Scale build-up on tubes or tube sheet.
- Cold condensate returns.
- Oxygen in water.

1. **OVER-FIRING THE UNIT:** This will cause excessive temperatures in the rear turning box. A point will be reached wherein the rate of heat transfer from flame through metal to water will not be great enough and a gradual increase in turning box temperature will occur. Tube end temperature will begin to rise to 750 degrees and thereby cause the tube joints to become loose. Leaks will occur if condition prevails for any length of time.

2. **THERMAL SHOCKING:** Thermal shocking of a unit describes a condition whereby the hot water in a unit is suddenly replaced with cooler water.

   If this condition occurs over an indefinite length of time, the tubes, contracting and expanding, may become loosened in their joints and may leak. This condition is particularly important in hot water boilers where the amount of water returned to the boiler is dependent on system pumps and system method of operation.

   If the boiler is not protected against cold return water, either through system design or operation, it is advisable to correct this condition at the earliest possible time as damage is a certainty.
York-Shipley Global manufactures a safety control which affords complete and positive protection against thermal shock of water boilers. This control is adaptable to any boiler, regardless of its make.

3. **HOT FIRING A COLD BOILER:** Hot firing a cold boiler is another method whereby tubes can be made to weep or leak. It is recommended that the unit be brought to temperature slowly by keeping it on a low fire position until the desired temperature is reached.

   **NOTE**
   The reverse of this procedure is what is referred to as thermal shocking.

   Leaks can also occur if a steaming boiler is suddenly shut down and the condensate return pump shut off at the same time. The unit will continue to steam and the water level continue to fall. A point will be reached where tubes will become exposed and overheated. The furnace tube is usually the point at which the failure is noticeable since sagging or blistering will occur near the hot refractory. This is the same type of sagging or blistering that occurs in a furnace tube if the unit is fired without water.

4. **SCALE BUILD-UP ON INTERNAL SURFACES:** Will eventually cause the unit to leak.

5. **COLD CONDENSATE:** Cold condensate return will eventually cause tubes to leak. It is recommended that condensate return temperature be controlled so the temperature never falls below 160ºF.

   Users of high pressure steam for processing where a large amount of make-up water is necessary should be careful to not only treat this raw water, but to heat the cold water. The easiest way is to apply a steam coil or heater in the condensate tank. If the tank is vented to the atmosphere, this method will assist in driving off dissolved oxygen before it reaches the boiler. It is still necessary to treat for oxygen through the administration of sodium sulfite according to the recommendation of the boiler water treatment company employed.

6. **OXYGEN IN WATER:** It is an extremely important item to be considered. Every owner of new or old equipment should be cautioned to look into this subject very carefully no matter what type of boiler he/she is using. Hot water boilers, low pressure steam boilers, and high pressure steam units deserve equal attention.

6-17. **Condensation**

Under certain conditions, water vapor is condensed from flue gas to form beads of moisture on tubes and the tube sheet. The amount of water produced is entirely dependent on the length of time these conditions prevail. Due to the high heat in the combustion chamber, the water remains in a vapor state and is transported through the flues with the products of combustion. The water will remain in the vapor state as long as it is not cooled to its "dew point" (the temperature at which water vapor turns to the liquid state).
Experience has shown that if the flue gases contact any surface which is at 140°F or lower, small beads of moisture will form on this surface and will continue to form as long as the surface remains at this temperature and gases scrub over it.

A gas fired hot water boiler is perfect for this type of condensation. If the boiler water temperature is lowered to approximately 140°F, moisture will begin to condense out of the flue gas. This moisture will accumulate on the tubes and on the tube sheet. If the unit remains at this low temperature for any length of time, a substantial quantity of water will be produced and will simulate a leaking boiler.

Some heating systems are designed to vary the temperature of water supplied to the unit heaters, radiators, convectors, etc., in accordance with the outside temperature. As the weather outside becomes warmer, the water temperature to the heaters is reduced. In most cases the boiler water temperature is lowered to control system temperatures.

If this boiler water temperature goes below 140°F, water will condense out of flue gases and water will drip out of the unit.

It is not recommended that system temperatures be controlled by lowering boiler water temperatures. It is recommended that system temperatures be controlled through a device that will blend enough water from the unit with water returned from the system to give the desired system temperature.

York-Shipley Global has a water temperature control that can be readily applied to any unit to provide for this type of control. Not only does the Aqua Temp Control eliminate the condensation problems, but it has a safety control to protect the boiler from thermal shock. The device does not, in any way, affect the indoor-outside control system. It is compatible with it.

6-18. Installation of New Tubes

1. **OVER-ROLLING TUBES:** When a tube is severely over-rolled, work harness occurs and other physical properties are changed. Over-rolling cold works the metal and reduces its ductility and may result in surface tears reducing its resistance to corrosion. The holding power of the rolled tube may also be reduced by over-rolling.

2. **TUBE INSERTION:** Before any new tubes are installed, all tube ends and tube sheets should be carefully cleaned. The preservative should be removed from the tube holes and the tube ends by wiping with carbon trichlorethylene or an equivalent solution. Any rust should be removed with a fine emery cloth. All tube ends and tube seats must be smooth and free from grease, rust, or other foreign particles. The tubes should be installed as soon as possible after they are received, and any tubes that become rusty before being expanded should be removed and re-cleaned.

All tubes should project just enough beyond the outside surface of the tube sheets to provide material for the proper beading of the end of the tube against the outside surface of the tube sheet. While being expanded, the tubes must be held to prevent them from moving in or out of the tube hole. The tubes should enter the holes parallel to the center-line of the holes and have even projection at opposite ends. One end of a tube should not be expanded unless the opposite end has been entered in its hole with approximately the correct projection.
SECTION VI - SERVICE AND MAINTENANCE

3. **LUBRICATION:** A prepared expander lubricant should be used to lubricate the expander rolls and mandrel. This type lubricant is easier to remove from the surface of the boiler than a mineral oil during the boiling out. Expanders should be washed frequently in kerosene to keep them clean.

   On straight expanding, it is advisable to use two expanders, letting one of them cool while the other is in use. The tubes in the bottom of a firetube boiler should be expanded first.

4. **EXPANDERS:** Expanders are designed to suit the size and gauge of the tubes and the thickness of the seats or tube sheet thickness. The rolls are tapered to expand the tubes parallel to the seat. The tools are long enough to expand the tubes one-quarter inch (1/4") to one-half inch (1/2") past the inside edge of the seat or tube sheet. This gives the tubes a slight bulge at the inside edge of the seat and prevents them from pushing out when the opposite end of the tube is expanded. The large end of the rolls are rounded off so they will not dig into the tube as the expander moves forward. A properly sized expander must be used for each joint.

5. **TUBE ROLLING:** To begin the rolling process, set the expander so the small end of the flaring roll has just started to enter the tube. The expander body will move into the tube as the mandrel is rotated in a clockwise direction. It is necessary to set the expander back farther from the end of the tube when expanding into a thin tube sheet.

   If the expander has been properly set, the tube will properly expand as the small end of the flaring roll reaches the outside edge of the seat. The small end of the flaring roll should not pass the outside edge of the seat.

   The expansion operation should be slow enough to prevent the tubes from heating up while being expanded. A tube that heats up while being expanded may shrink away from the seat when it cools off.

   It is better to have the tubes slightly under-rolled than over-rolled as the under-rolled tubes can be re-rolled if they leak on the hydrostatic test. Over-rolled tubes may have to be removed and new tubes installed.

   When a tube has been properly expanded, it will have a slight bulge, about one-quarter inch (1/4") past the inside seat. The diameter of this bulge should be approximately 0.20 inches greater than the original diameter of the tube hole.

6. **FLARING:** The flared position, or bell, of the tube to the outside of the tube sheet should equal the diameter of the tube plus one-eighth inch (1/8").

7. **SIGNS OF OVER-ROLLING:** When a tube has been sufficiently expanded, there will be a slight indication of flaking of the mill scale or paint generally indicates over-rolling. If the flaking starts, the expanding operation should stop.

   **NOTE**
   Carbon moly or chrome moly tubes may start to flake before they have been properly expanded. A small amount of flaking in these alloy tubes is not objectionable.
6-19. Repair or Replacement of Tubes

Repair or replacement of boiler tubes is sometimes necessary due to scale, shock, corrosion, or pitting.

1. **TOUCHING UP** TUBES: It is normally only necessary to "touch-up" the boiler tubes. It is recommended that a **hand tube roller** be used for this process. To touch up weeping tubes, turn the hand operated tube roller a turn and a half from the point where the expander takes hold and starts to expand. Extreme care should be taken when performing any tube rolling operation to prevent the bead of the tube from coming away from the tube sheet. A .002" feeler gauge should be used to check depth. If the tube bead is away from the sheet more than .002", the tube end must be rebeaded.

2. **REMOVAL OF EXTERNAL SCALE:** If the tube sheet is covered with scale or salts, great care should be taken to remove this scale from underneath the tube bead. Any accumulation of scale under the bead will act as an insulator and retard the flow of heat from tube bead to tube sheet. The tube end will then become excessively overheated and fail.

3. **TUBE BEADING:** Tube material is mechanically upset and pushed in a solid mass against the tube sheet. There should be no cavity under the bead to act as an insulator and cause overheated tube ends. A good upsetting operation can be secured through flaring the tube end, after rolling, approximately 7º off the vertical.

4. **TUBE REMOVAL:** When removing tubes, be sure not to damage tube sheet holes. If fire cracks have developed, or cracks in ligaments started, remove the entire pass of tubes and tube sheet.

5. **HYDROSTATIC TESTING:** The unit should be subject to a hydrostatic test after the touch-up or new tube installation.

6-20. CORROSION

Corrosion is a major factor in shortening the useful life of boiler tubes. The following corrosive conditions may arise due to improper water side boiler treatment.

- Atmospheric Corrosion
- Fire Side Corrosion
- Pitting Corrosion
- Water Line Corrosion

1. **ATMOSPHERIC CORROSION:** A piece of steel in the middle of a desert will not rust for a long time, but near the shores of a lake, ocean, or stream, it will rust quite rapidly. Steel does not corrode appreciably in dry air — but only in the presence of moisture.
Steel also will not corrode in clean, alkaline, or freshly boiled water, if air is kept away. However, corrosion of the steel takes place as soon as the water is exposed to air and has a chance to absorb oxygen.

2. FIRE SIDE CORROSION: Corrosion on the fire side of boiler tubes is caused by moisture condensing from the atmosphere during periods of shut-down or from flue gases during operation. This type of corrosion is especially troublesome in boiler installations near bodies of water or where the atmosphere is humid and is accelerated by the use of high-sulfur fuels. Sulfur gases may condense on tube surfaces when the boiler is operated at temperatures between 160°F and 240°F, depending on the kind of fuel and methods of firing.

Some boilers, such as those in greenhouses, operate at water temperature of 140°F to 150°F. Under such conditions the condensing gases form sulfurous and sulfuric acids attack the tubes and the result is corrosion. If the percentage of sulfur in the oil is high, this situation is worsened during shutdown periods because of high humidity in the air. When shutting down the boiler under such conditions, the fire side tube surfaces should be brushed and flushed to remove the winter's accumulation of soot and other products of combustion. This should be followed by blowing air through to dry out these surfaces. In extremely humid locations the stack should be disconnected and a tray of unslaked lime placed in the ash pit to keep the fire side dry. This lime must be renewed whenever it becomes mushy.

3. PITTING CORROSION: Pitting is probably the most destructive form of corrosion to affect the water side of boiler tubes. Its damage is especially severe in firetube boilers. It is recognized by the presence of randomly scattered pits. The frequency of the pits is, to a large extent, determined by the degree of acidity or alkalinity of the water. Acidity and alkalinity are expressed by chemists in terms of a scale of pH values (hydrogen ion concentration) on which a strongly acid solution (strong muriatic or sulfuric acid) is rated as one and a strongly alkaline (concentrated caustic soda) solution is rated as 14. A neutral water has a pH value of 7. Slightly acid and slightly alkaline water conditions (pH 5 to 9.4) are especially conducive to the formation of pits.

The rate of corrosive attack is increased by dissolved oxygen in the boiler water. Dissolved oxygen corrosion works in three general ways.

- air bubble pitting,
- scab pitting, and
- soft scab pitting

a. AIR BUBBLE PITTING: Caused by the formation of air bubbles on boiler metal surfaces under stagnant conditions. Surface waters are generally saturated with dissolved oxygen because of their exposure to the atmosphere. Oxygen may be present in varying amounts, depending on the temperature of the water. Oxygen solubility decreases with the increase in water temperature.
Well water usually contains less dissolved oxygen than surface water and in deep well supplies, dissolved oxygen may be absent. Dissolved carbon dioxide may be present, however, is also a corrosive to steel.

When a boiler is filled with oxygen saturated water, small increases and fluctuations in water temperature tend to throw out the dissolved air as small bubbles. These bubbles readily attach themselves to any convenient surface. This can be demonstrated by filling a clear bottle with cold tap water and allowing it to stand for a few days. The bubbles may then be seen on the sides of the bottle.

In some cases, the pits occur in a straight line. Straight line pitting is almost always located along the top of the boiler tube. Air bubbles remain easily on the top of horizontal tubes since they are less affected by water circulation in these locations. The upward water circulation also causes an eddy effect above the tubes. Conditions are generally more conducive to corrosion.

It is possible to minimize the effect of pitting during stagnant periods by adding sodium chromate to the water at the rate of 1 lb. per 50 gallons of boiler water or adding sufficient caustic soda, usually 1/2 lb. per 100 gallons to bring the pH of the water about 10.5 or 11.0. These chemicals may be left in the boiler during operation to continue protection of the metal surfaces.

It is recommended that when a boiler is freshly filled that it be fired immediately until the boiler water reaches a relatively high temperature. Most of the air in the water will then be driven off. In the case of a steam boiler, it should be fired long enough and hard enough to take some steam from the unit to completely deaerate the water in the boiler. It is better when shutting down to leave the deaerated dirty water in the boiler than to drain and refill without firing.

b. **SCAB PITTING:** Occurs under operating conditions where penetration from air bubble corrosion has started and no attempt has been made to inhibit the corrosion characteristics of the water with chemicals. It is possible to almost eliminate pitting at operating temperatures by maintaining the boiler water above the theoretical pH of 9.4. A maximum value of 11.09 is considered good practice.

c. **SOFT SCAB PITTING:** Occurs in boiler drums, superheater tube surfaces, steam lines, and other surfaces where the metal is not submerged during idle periods.

4. **WATER-LINE CORROSION:** Water-line corrosion in vertical firetube boilers is due to an excess of oxygen in the boiler water and/or very bad water conditions may be acid. In both cases the tubes fail by thinning, which is most pronounced at and slightly below the water-line. Air bubble pitting corrosion is attributed to differences in oxygen concentration which exist in the water at the water-line and the concentration in the water below the water-line. Excessively hard waters cause a hardness scale to deposit on the tube and shield the tube from oxygen, thus causing corrosion at the water-line in the same manner as air bubble pitting.

Water-line corrosion may be avoided by making certain that boiler water is sufficiently alkaline and free of oxygen. If the boiler water is so acid that it dissolves the tubes, the only solution is to use chemicals to make the water alkaline or to develop a different source of water.
6-21. General Rules for Avoiding Corrosion

In reviewing the various types of corrosion encountered in boilers, it is evident that water conditions play an important part in the failure of boiler tubes. Experience has verified oxygen dissolved in the feed water as air causes more trouble to boiler users than any other one condition.

There are eight general rules to help boiler operators avoid serious tube corrosion problems and obtain longer tube life with fewer unscheduled shutdowns and more economical maintenance.

1. Keep all boiler fittings and piping tight to keep air out as much as possible.

2. Boil out the boiler with an alkaline cleaner such as trisodium phosphate or a combination of caustic soda and soda ash or one of the newer detergents currently available. Protective coatings are applied to new tubes to prevent rusting during storage and transit, and will cause corrosion if left on the tubes during operation of the boiler.

3. Bring a steam boiler to a good steam output as soon as it is freshly filled to deaerate the water. Heat the water in a hot water boiler to 180°F for the same reason.

4. Add sodium chromate or caustic soda to the water in the quantities recommended.

5. Preferably, use a fuel with low sulfur content to avoid the corrosive action of sulfur gases.

6. Brush, flush and dry out the insides of firetubes regularly to remove soot and other products of combustion. This will help prevent the accumulation of moisture and condensed sulfur gases.

7. In greenhouses or in damp locations, put a tray of unslaked lime in the ash pit to absorb moisture and close the boiler. Inspect this lime occasionally and renew when it becomes mushy.

8. Prevent water leakage and do not drain water out of the system frequently. These add to the need for additional make-up water, result in loss and dilution of treatment and introduce air into the system.

6-22. Scale Formation

Scale formation on the water side of boiler heating surfaces is caused by the contact of certain impurities in boiler water with the hot surfaces. Most common among these impurities are calcium, magnesium, and silica. The calcium or magnesium may unite with sulphates or magnesium which are scale forming.

Calcium is common in raw water because it is present in many forms, as marble, limestone, and chalk. Magnesium in various forms is found in raw water from many sources. A well known form is magnesium sulphate. Silica found in sand and glass forms an exceedingly hard, dense scale - glasslike.
Scale forming water is said to be "hard." This hardness is either temporary or permanent or both. The temporary hardness may be eliminated by heating the feed water to about 212°F in an open or deaerating heater where the salts causing temporary hardness are precipitated. The permanent hardness must be controlled by treatment in water softeners or by treatment in the boiler.

There are two definite objections to scale on boiler heating surfaces.

1. Scale is a very efficient "non-conductor" of heat. The degree of non-conduction varies with its density. Its presence in appreciable thickness means less heat absorption by the boiler water, with consequent loss of boiler efficiency.

2. Since scale is a poor heat conductor, the heating surface is insulated from boiler water on one side and exposed to hot gases on the other. Surfaces may reach a dangerously high temperature and serious damage, including rupture of tubes and boiler shells, may result.

Scale formations often increase with the rate of evaporation. Scale deposits will often be heavier where the gas temperatures are highest. A coating of scale 1/16" thick on tubes or boiler surfaces exposed to radiant heat may cause failure of the tubes and surfaces.

| DANGER |
| Scale deposits and consequent bags and blisters frequently result in dangerous explosions due to leaking of the boiler. |

| NOTE |
| If water requires a small amount of soap to make an easy lather, the water is considered "soft." If consider-able amount of soap is required to produce the same amount of lather, the water is considered "hard." |

**Feed water.** Pure water is a combination of hydrogen and oxygen; that is, two atoms of hydrogen combine with one of oxygen to form H\(_2\)O. Water is a good solvent. As a result it does not remain in this pure state very long. As the rain descends, it picks up gases form the atmosphere and dirt in the form of dust and soot. Flowing over and through the ground, over limestone and gravel, through sewage systems and other channels, it finally finds its way to the boiler. By this time it contains considerable impurities.

Many of the impurities are eliminated by filtering and treatment. After these undesirable ingredients have been removed, the water passes to the boiler. With evaporation, the impurities are left behind. As more water is added and in turn evaporated, additional
impurities remain. After awhile, the water becomes saturated with these salts or impurities and they drop out of solution and adhere to the heating surfaces. Certain salts produce a soft sludge, and others a hard brittle scale. Each depends on the chemical reactions, temperature, and pressures involved.

The chief scale-forming salts are those of calcium and magnesium. Magnesium sulphate is a salt commonly found in boiler water and forms a soft, sludgy mass not very harmful, which can be removed by blowing down. When present with calcium carbonate, it forms a very brittle scale difficult to remove. Calcium sulphate also produces a hard scale. Many salts which do not form a troublesome scale at ordinary temperatures react very differently at higher pressures and temperatures.

6-23. Bagging

Bagging is due to overheating, caused by an accumulation of scale which prevents the water from reaching the surface of the metal. Under the action of heat, the plate becomes soft and yielding to the internal pressure and produces a bag.

6-24. Blistering

Blistering results in somewhat the same fashion as bagging. The entire sheet, however, does not bulge but, owing to imperfect material, a separation of metal occurs; under the influence of heat this produces a blister.

Many waters have what is known as "temporary" hardness. By the action of heat, these impurities can be precipitated and removed. This heating is usually done in heaters by boiling at atmospheric pressure and venting some of its gases to the atmosphere, liberation of both oxygen and carbon dioxide results.

Pre-treatment of feed water is frequently employed. By the addition of lime and soda ash, harmful scale forming salts are precipitated. The analysis of feed water and its application are a special branch of engineering. No representative of York-Shipley Global is permitted to administer, recommend, or in any way become involved with treatment of boiler water for any York-Shipley Global product.

| IMPORTANT |
| No materials for the prevention of scale, priming corrosion, etc., should be employed unless the composition and behavior of these chemicals are Understood and professionally administered. |
If precautions are taken to make frequent examinations of the boiler heating surfaces, it is possible to eliminate scale by one of the methods outlined. Many modern plants are operating continuously at very high ratings without any difficulty in this respect. By combining a careful plan of pre-treatment in addition to internal treatment, boring of the tubes can be eliminated.

6-25. Foaming

Foaming is usually due to a collection of impurities on the surface of the water which retard the escape of steam. It may be the result of dirty water, certain types of organic matter, oils in solution, the presence of too much soda ash, suspended matter, and/or oil in the presence of sodium carbonates. When foaming occurs, the surface blowdown should be used if possible. If this is not possible, alternate feeding water and blowing down to eliminate the trouble. If oil or grease appear in the water and foaming continues, the best procedure is to take the boiler off line as soon as possible. It should then be cleaned by placing it in a solution of soda ash and gently boiling for some time. If necessary, the solution can be emptied and the process repeated.

Oil is very injurious to a boiler for in addition to causing foaming, it adheres to the tube surfaces and being an excellent insulator, frequently causes bagging and rupture. If foaming is due to suspended matter in the water, it can be remedied by filtering. If foaming is due to the chemical nature of the water, proper pre-treatment will correct the difficulty. If oil from exhaust steam is the cause, it can be eliminated by the use of separators and traps.

6-265. Priming

Priming is the result of violent agitation of steam bubbles from the water's surface, resulting in moisture carryover. It may be due to poorly designed steam drum, extremely high ratings or a sudden full releases demanded of the boiler while under pressure through the action of quick opening steam valves.