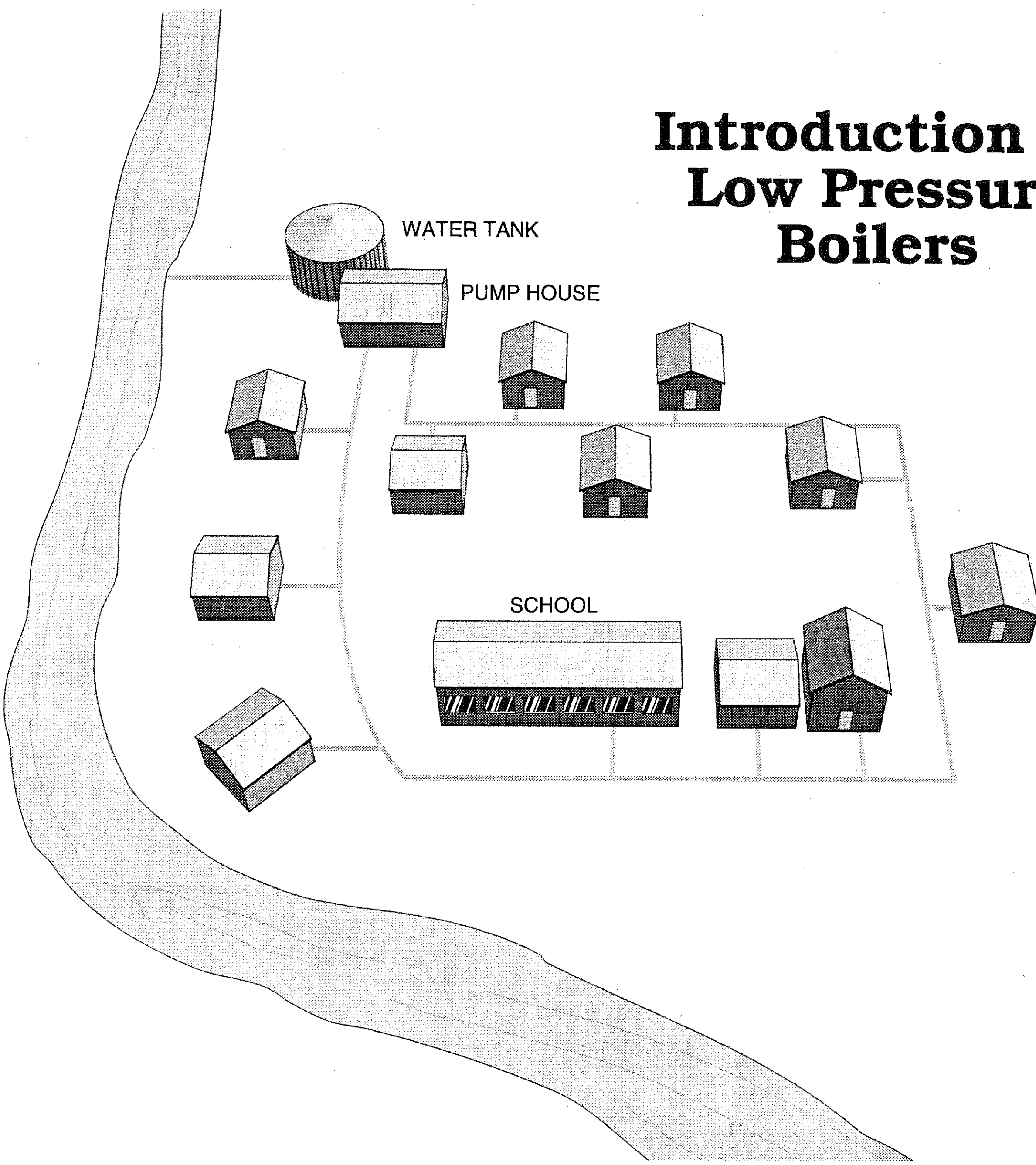
O & M of Small Water Systems



Introduction to Low Pressure Boilers

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O & M of Small Water Systems

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- Blast tube
- Boiler
- BTU
- Burner head
- CAD cell
- Combustion
- Combustion chamber
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INTRODUCTION TO LOW PRESSURE BOILERS

INTRODUCTION

Function

Low pressure **boilers**[1] are used by water systems in the Arctic to directly heat water and heat utilidors in order to prevent freezing. On occasion these same systems are used to heat the water prior to treatment in order to enhance treatment. (Cold water is very difficult to treat for color or turbidity removal.)

Module Content

The contents of this module will be focused on boilers and **heat exchangers**[2] used in Arctic rural Alaska. The contents provides identification of basic boiler and heat exchanger components, routine operation and maintenance procedures and typical problems and solutions for these boiler systems. The module also provides information on basic theory of oil burners and heat transfer.

Intention of Material

This written material is intended to be used to introduce waterworks operators to the process of heating water through the use of low pressure boilers. The material is also intended for use as an introduction to a boiler maintenance course.

Not in Module

This training module is not a substitute for the boiler maintenance training provided by PHS in the State of Alaska. With few exceptions there are no details provided on boiler performance testing, boiler repair or troubleshooting. And finally, there is not discussion included on the use of boilers or other heating systems for any purpose of than those directly associated with drinking water.

SYSTEM COMPONENTS

Complexity of Systems

The components and complexity of a low pressure boiler system may vary widely from very simple to highly complex. The system described in this training module is a theoretically typical system of medium complexity. What this means is it may not look like any system. However, the major components described in this material will be similar to the vast majority of systems used in rural Alaska.

Typical System

A "typical" boiler system used to heat potable water systems is composed of a oil fired low pressure water boiler. Hot water and **glycol**[3] is circulated from the

1 **Boiler** - A device made of cast iron, liquid. The liquid is heated as a result of combustion of a fuel in a space inside of the boiler.
2 **Heat exchanger** - A piece of equipment where heat is transferred from one substance to another.
3 **Glycol** - Common name for ethylene or polyproplene glycol, a colorless, thick, sweet liquid used as an antifreeze. Ethylene glycol is highly toxic and should not be used.

boiler through a heat exchanger. Heat is transferred from the glycol to the potable water within the boiler.

Systems

The typical boiler system is composed of six subsystems. These subsystems are:

- Fuel system
- **Combustion**[4] system
- Exhaust system
- Hydronics system (water or glycol)
- Control system
- Potable water system

In the following discussion each system will be discussed independent of the others.

FUEL SYSTEM

TANK FARM

Description

Our fuel system starts at the village **tank farm**[5]. The farm may be composed of two to ten round 8000 gallon tanks mounted vertically. These tanks are commonly mounted above the ground on pallets or on piling. Because the piling provides some protection against damage as a result of ground heave, it is the preferred design.

[4] **Combustion** - The rapid union of oxygen with an element or compound that results in the release of heat.
[5] **Tank farm** - An area with two or more tanks used to contain liquid, usually fuel.

Spill Protection

The environment is protected from an accidental spill of fuel by a berm around the tank farm. The interior of the berm is lined with Hypolon™, a man-made fabric that contains oil products.

Piping

The piping in the tank farm and any piping leading between the tank farm and the water plant should be made of seamless **schedule 80**[6] black iron pipe, with butt or socket weld joints. The piping should be wrapped with insulation and covered with a water resistant coating. Piping leading to the water plant is commonly installed above ground. In such cases it should be marked and protected from winter snow machine activity.

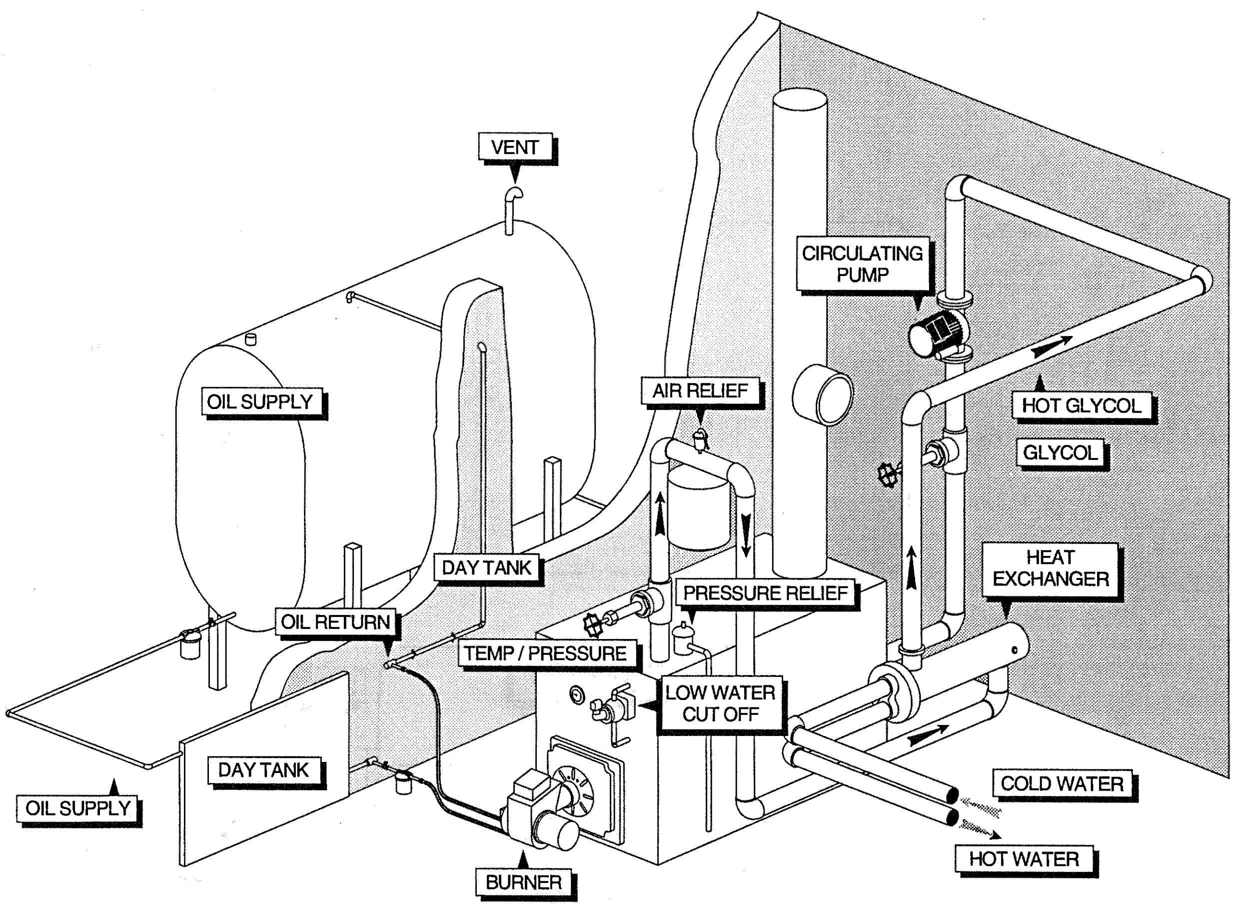
Oil Type

#1 Arctic grade diesel is used as the fuel source for the burner assembly in the boiler.

SITE STORAGE TANK

The Tank

A 500 gallon, above ground tank is commonly placed just outside the plant. The separation distance between water sources and fuel tanks clearly states that this volume must be 500 gallons or less. If above that level the tank must be at least 100 feet from the



[6] **Schedule 80** - As it pertains to pipe - A welded or seamless pipe that corresponds to ASA B36.10. This pipe has the same outside diameter as standard steel pipe which is called Schedule 40 pipe but a greater wall thickness.

well or surface water source. The tank is normally mounted on a wooden or concrete pallet or on steel legs. The tank is mounted at a slight angle sloped away from the outlet. This slope allows water that condenses in the tank to go to the low point, away from the inlet.

Vents

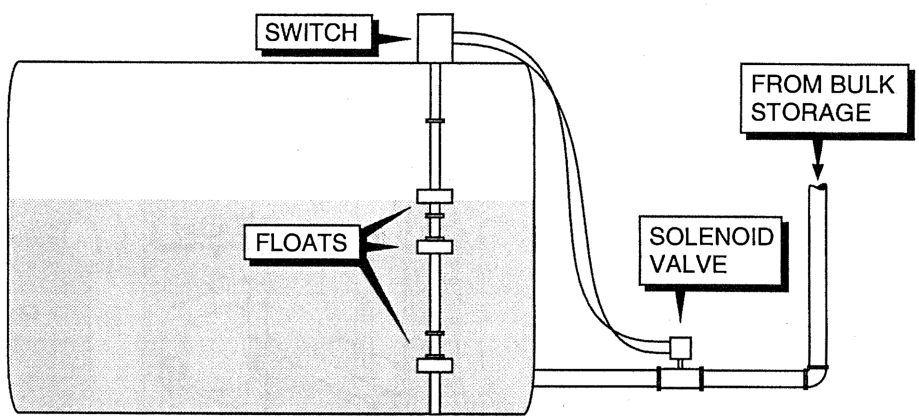
The site tank is commonly vented with a screened vent placed in the top of the tank. The vent prevents the tank from expanding during filling by allowing air to be forced out of the tank. The vent is double action, by allowing air into the tank during withdraw it prevents a vacuum from forming in the tank. A vacuum could damage the tank and prevent oil from flowing out of the tank.

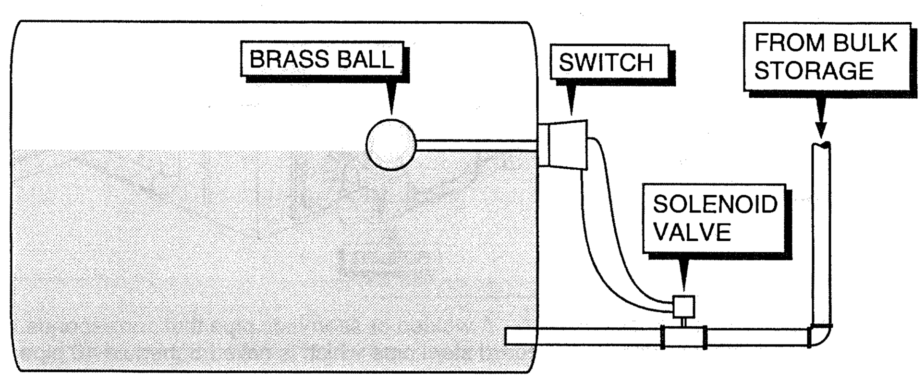
Moisture Problems

One of the negative effects of the tank vent is allowing the air into the tank. Most air brings with it moisture. This moisture can condense on the inside of the tank and foul the fuel supply.

Filling the Tank

The tank may be filled manually or be connected directly to the fuel farm. When connected directly an isolation valve will be required on the fill line. In many cases the direct connection fill process requires a pump. When a pump is used, most commonly it is a gear type pump.





Level Controls

The site tank may be filled automatically or manually. When the fill is automatic there are two common control systems. One uses a single float which operates a solenoid valve in the fill line. The second uses a two float system, on and off, connected to the same type of solenoid valve.

Piping

Besides the vent line, there are two other lines on a site tank. These lines are the fill and draw lines. They should be made from 3/4 inch seamless schedule 40 or schedule 80 black iron pipe. Threaded connections are acceptable. The fill line commonly enters the tank at or near the top. The draw off line is usually placed six inches up from the bottom. Flexible connections should be placed between the tank and the lines to protect the lines from breakage during tank movement.

Protection of Environment

The area around the tank should be protected from contamination from an accidental fuel spill by placing a Hypolon™ covered berm under the tank. The berm should form a dike large enough to contain the full volume of the tank.

DAY TANK

Function

In environments where the ambient temperature is below 0°C, a **day tank**[7] is necessary in order to warm the fuel to a proper operating temperature. The day tank is normally a 10 to 20 gallon vertical tank placed inside of the boiler room.

Tank Fill

The day tank may be filled by gravity from the site tank or by a transfer pump. If a transfer pump is used it is commonly a Webster or Suntec rotary gear type.

Piping

There are five pipes on the day tank. They are all 3/4 inch schedule 40 black iron pipe with threaded connections. One pipe is a screened vent that must extend above the height of the vent on the site tank. The inlet from the site tank is usually near the top on one end of the tank. On the opposite end of the tank are the supply and return lines leading to the boiler(s). The draw line is usually 2 to 3 inches from the bottom of the tank and the return line near the top of the tank. The fifth line is the drain. The drain is close to the bottom of the tank and can be at either end.

Valves

Brass single disk gate valves are placed on the supply and drain lines.

Boiler Supply Piping

The line leading from the day tank is 3/4 inch black iron. Commonly this line is reduced at a tee or 90° Ell to 1/2 inch. A brass gate valve is placed in the 1/2 inch line for isolation. Following the gate valve is a fusible valve that will close automatically in case the

[7] **Day tank** - A small, 10 to 20 gallon tank placed inside of a building to preheat the fuel oil as it travels from the site tank to the burner.

room temperature exceeds 140°F. Once closed by heat, this valve must be replaced before oil can again be supplied to the boiler. Following the fusible valve is an oil filter, General 1A-25 is the most commonly used. Just after the filter is a second brass gate valve used for isolation during repair of the burner. From the gate valve the piping is changed to type L seamless copper tubing with flare connections. The copper tubing leads directly to the burner pump. To reduce the impact of normal vibration from the burner motor onto the copper tubing, the tubing is usually installed with three loops. This allows for a great deal of damping of the vibration and reduces the possibility of breakage of the copper.

Drip Pan

Placed under the filter is a drip pan usually 24" X 16" X 1/2' deep.

COMBUSTION SYSTEM - ALSO CALLED THE BURNER

Burner

The burner housing is the framework that will hold all of the components except the **combustion chamber**[8], that makes up the combustion system.

Pump

The heart of the combustion system is the pump. The pump is attached to one side of the burner housing. Common brands of pumps are the Sundstrand, Danfoss, or Webster. These are all **Trocholidal gear-wheel set**[9], type pumps with the ability to provide 100 psi of discharge pressure.

Pump Connection

The brands of pumps identified above have two possible connections for the inlet oil. The copper tubing from the day tank is attached to one of these connections. The pump contains a pressure release valve that returns all unused oil to the day tank via the return line. There are two other connections on the pump. One is for the line leading to the **nozzle**[10] assembly and the other is the air bleed port. This is used to remove air from the system after rebuilding or replacing a filter.

Pressure Gauge

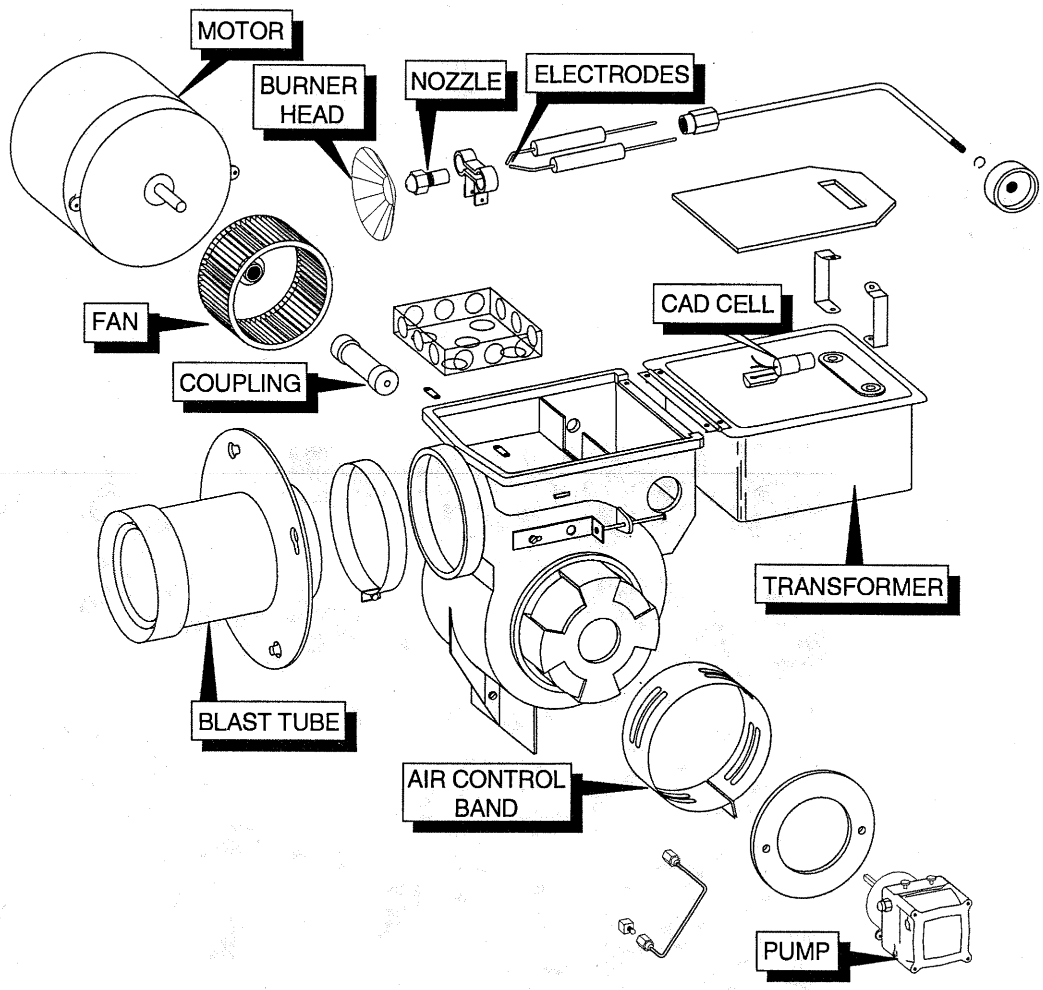
A pressure gauge is an essential tool to determine if a pump is working properly. A gauge should be installed on the nozzle discharge port or in a special outlet connection designed for a gauge.

Solenoid Valve

A solenoid valve is located in the nozzle line, between the pump and drawer assembly, and is on the inlet oil supply. The solenoid is closed if there is a loss of flame in the combustion chamber to prevent the chamber from being flooded with oil. The solenoid valve also provides clean on off operation of the oil supply. The

[8] **Combustion chamber** - The physical area inside of a boiler in which combustion takes place.
[9] **Trocholidal Gearwheel set pump** - A special high pressure gear type pump. A positive displacement pump.
[10] **Nozzle** - A device used to atomize oil.

valve is connected to a time delay that keeps it off line during a start-up for 3 to 5 seconds to allow the squire cage fan to come up to full speed, supplying the needed air for combustion.



Motor

The pump is driven by a 1725 or 3450 rpm single phase motor. The motor is mounted on one side of the burner assembly and the pump on the other.

Coupling

Energy is transferred from the motor to the pump with a coupling. The coupling is made of rubber or neoprene with removable hard plastic ends. This process allows several different motor and pump brands and styles to be connected together. When a new pump is purchased, it is supplied with a coupling kit, containing the various connectors needed.

Fan

Driven by the motor, but placed in the center of the burner housing is a squire cage type fan. This fan is used to supply air to the burner for combustion. Air inlet controls are built into the pump side of the housing.

Air Tube

Attached to the air discharge side of the burner assembly is the air or **blast tube**[11]. The blast tube contains the nozzle assembly and electrodes. Its function is to contain the air around the nozzle.

Burner Head

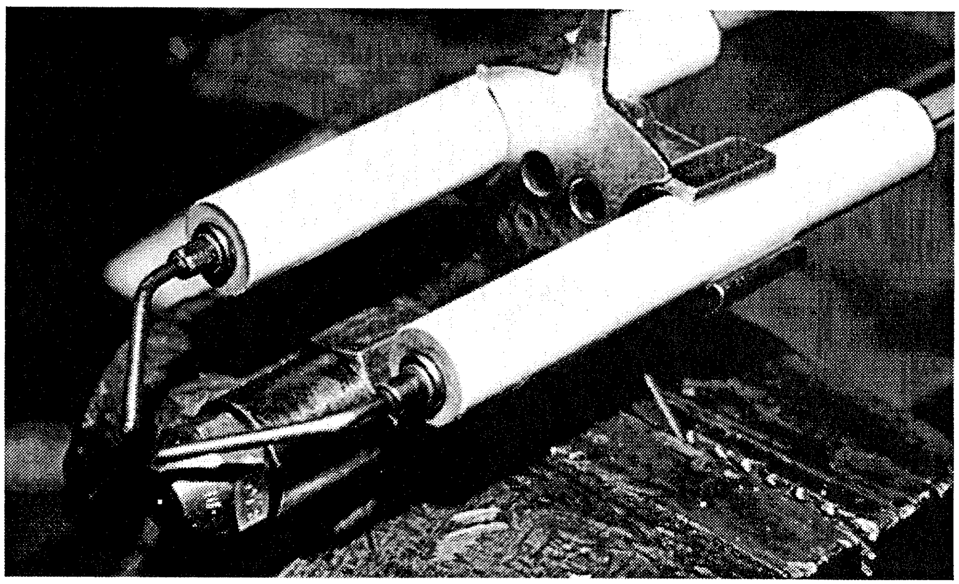
Placed at the end of the blast tube is the **burner head**[12]. The function of the burner head is to cause the air to move in a swirling action. This improves combustion. There are several types of burner heads. The most common used in Alaska is the flame retention type.

NOZZLE TUBE ASSEMBLY

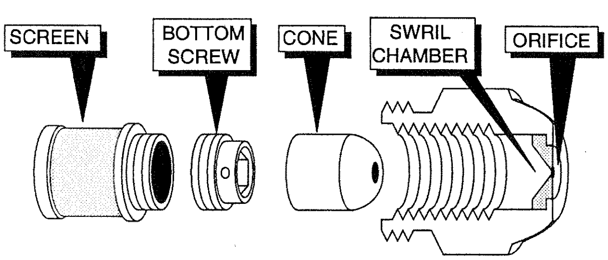
Nozzle Tube

The nozzle tube assembly, also called the drawer assembly, starts with an oil tube which is connected to the burner assembly. This connection holds the nozzle tubes in place and provides a connection for the oil line to the pump. On the end of the tube is the nozzle.

Electrodes & Nozzle assembly

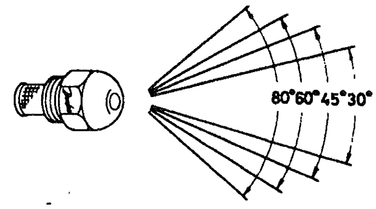


Nozzle

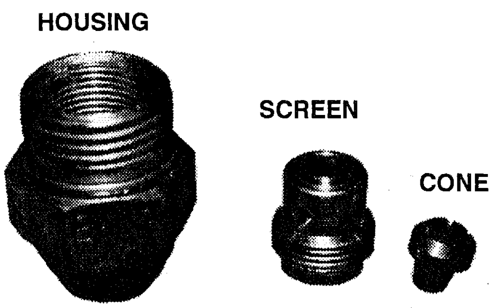


The nozzle **atomizes**[13] the oil so it can mix with the air and burn. The nozzle is composed of a **orifice**[14] of controlled size and a built-in filter. The orifice controls the shape and angle of the spray. There are several major brands of nozzles used in rural Alaska; Monarch, Delavan, Hago and Danfuss are the most common. On the edge of the hex portion of the nozzle will be three sets of figures. One gives the gallon per hour rating of the nozzle, one is a letter indicating the shape of the oil pattern and one is the angle of the nozzle. The gph rating is for 100 psi discharge pressure.

11 **Blast tube** - A tube extending from the frame of the burner assembly into the combustion chamber and holding the nozzle tube assembly and electrodes.
12 **Burner head** - A device placed on the end of the blast tube, used to cause the air to swirl as it passes the nozzle.
13 **Atomize** - To break up a liquid into a fine mist.
14 **Orifice** - An opening, usually round of a controlled and specific size.



Monarch



The following diagram gives the letter designation and pattern for Monarch nozzles.

R = Solid

NS = Hollow

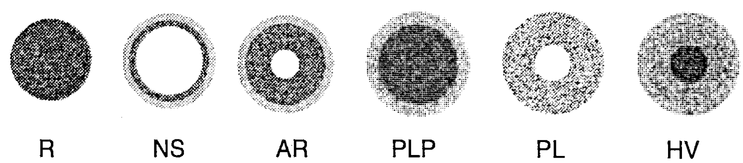
AR = Special solid

CC =

PLP = Semi solid

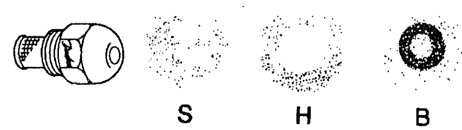
PL = Hollow

HV = Scotch Marine



Danfuss

The following diagram gives the letter designation and pattern for Danfuss nozzles.



Delavan

The following diagram gives the letter designation and pattern for Delavan nozzles.

A = Hollow

B = Solid

W = Semi-hollow

Hago

The following diagram gives the letter designation and pattern for Hago nozzles.

H = Hollow

P = Solid

CS = Extra Solid

S = Solid

Electrodes

Mounted above the nozzle are the electrodes. The electrodes provide an electrical spark that ignites the oil.

They are metal components molded into porcelain.

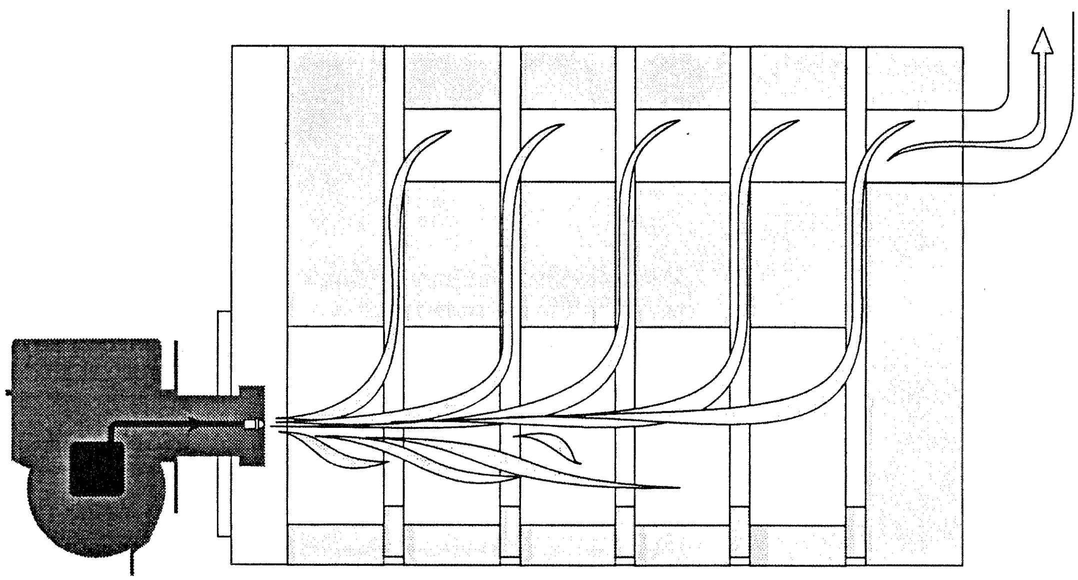
Power for the electrodes is provided by the high voltage ignition transformer mounted next to the primary controls.

CAD Cell

Mounted above and back of the electrodes is a **CAD cell**[15]. This is a light sensitive cadmium sulfur cell. The CAD cell is designed to shut off power to the electrodes and close the oil solenoid valve should there be a loss of flame or the flame fails to appear at start-up. CAD cells are commonly available with 15, 30 or 45 second time delays. This is the length of time after loss of flame before action is taken.

Combustion Chamber

Combustion of the oil with the air occurs in a large open space in the lower portion of the boiler. This space is called the combustion chamber. The chamber extends the length of the boiler.



[15] **CAD Cell** - A cadmium sulfur device used to check for the presence of light.

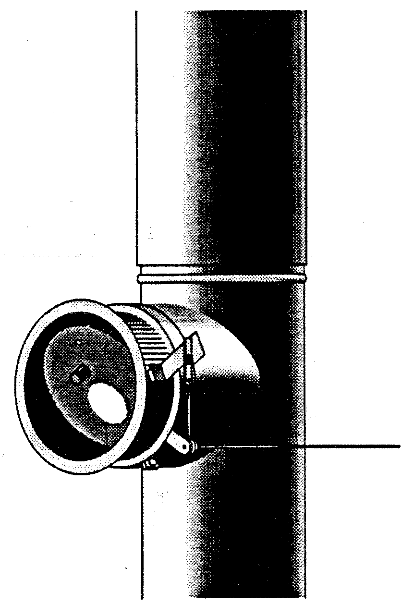
EXHAUST SYSTEM

Combustion Chamber

The exhaust system starts in the combustion chamber. The combustion of the oil to flame must be completed in the combustion chamber. There should be no combustion in the exhaust system.

Stack

Gases and hot air escape the combustion chamber and collect in the stack. The stack is commonly made of 3 foot 24 gauge galvanized steel pipe. The stack extends from the boiler to the chimney.



Draft

In order for the gases to escape from the combustion chamber and up the stack, a draft must exist. A draft is a movement of air through the combustion chamber to the outside. A portion of this draft is a forced draft caused by the squirrel cage fan. A portion of the draft is a natural draft. One of the problems with natural draft is they are subject to variations based on changes in the atmospheric pressure and on how the wind blows across the chimney. A fluctuation in the draft can cause a fluctuation in the pressure in the combustion chamber as well as the amount of air available. This causes a change in the effectiveness of the combustion.

Barometric Damper

To reduce the impact of changes in natural draft conditions, a barometric damper is placed in the stack just above the boiler. As barometric conditions change, the door on the damper will open and close allowing more or less air to flow through the damper and out the chimney balancing the difference between the air pressure in the room and the air pressure outside. The damper thus prevents a change in air pressure and flow through the combustion chamber, maintaining a fixed combustion process and fixed air to oil ratio.

Chimney

A chimney is that portion of the exhaust system that protrudes through the ceiling and roof and extends to the outside. The chimney may be made of brick, insulated steel or concrete blocks.

Spark Arrester

When the roofing material is made of materials that would easily burn, such as wooden shakes, a spark arrestor is placed on top of the chimney. A spark arrestor is composed of a series of expanded metal screens and heavy gauge wire mesh. This material collects and holds sparks and large pieces of soot that may occasionally find their way up the chimney.

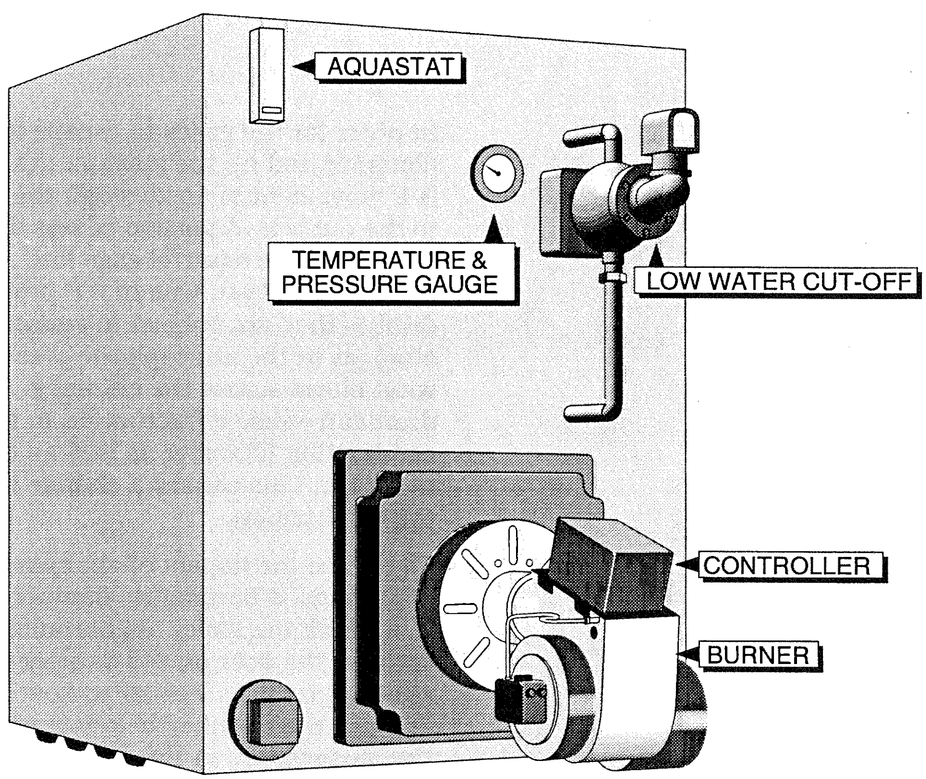
Weather Cap

It is never desirable to have rain or snow fall down the chimney, it can reduce the efficiency of the boiler and prematurely deteriorate the stack. To prevent this problem, a weather cap is placed over the top of the chimney. A weather cap is designed to allow the smoke and gases to escape and at the same time prevent rain from falling directly into the chimney.

HYDRONIC SYSTEM

Defined

The hydronic system is the fluid system that is contained within the boiler and extends to the boiler side of the heat exchanger.



Glycol

Many communities use glycol or a 50/50 mixture of glycol and water in the hydronic system. Glycol prevents the piping from freezing, should their be a boiler failure. Only propylene glycol should be used.

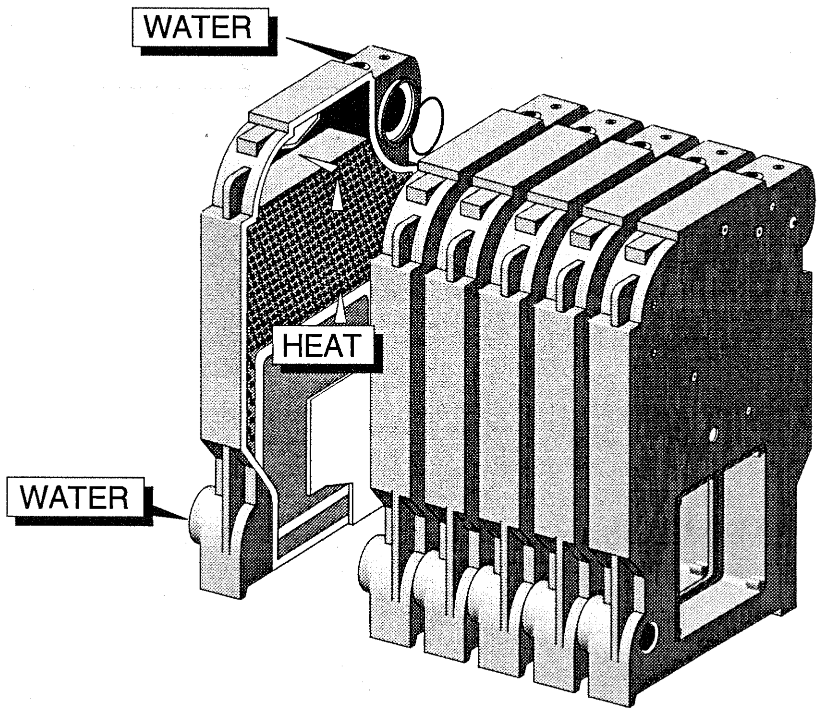
BOILER

Multiplate

The boilers used in this system are low pressure multiplate boilers. The boiler is composed of a series of cast iron sections. The sections are designed with the combustion chamber in the lower part. Each section is hollow and will hold water. The sections, when fastened together, have spaces between them that allow heat to pass from the combustion chamber up between the sections and into the stack.

Fluid Flow

Fluid (water or glycol) flows in the bottom rear of the boiler and out the top front of the boiler. The inlet and outlet connections are usually on opposite corners.



PIPING SYSTEM

Piping & Valves

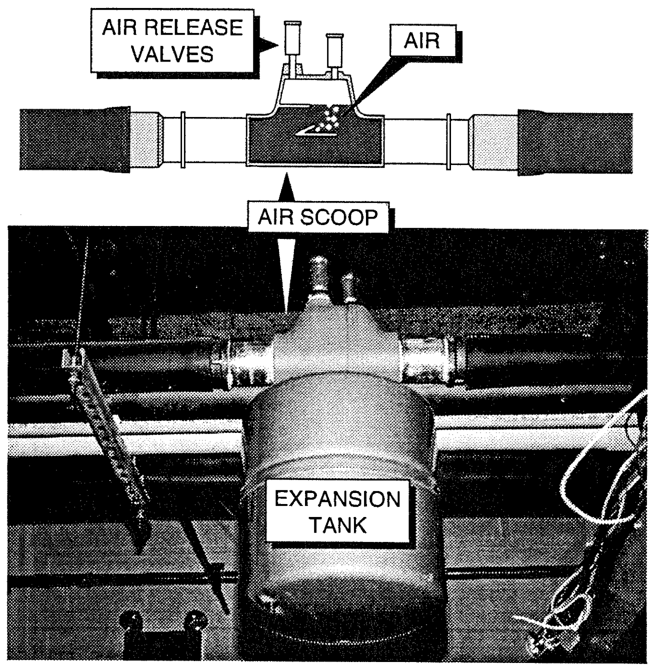
The inlet and outlet lines are commonly made of copper and have single disk brass gate valves as isolation valves.

Expansion Chambers

Because fluid has a tendency to expand when heated, expansion chambers are placed along the piping system. These chambers are usually a Airtroll tank attached under an air scoop. The tank has a diaphragm separating the fluid from air cushion. When the fluid expands the air is compressed. When the fluid cools and contracts, excess fluid in the tank is forced back into the system and thus system pressure is maintained.

Air Scoop

All fluids contain air. When heated, air can cause pipe hammer and can damage pump impellers and control valves. A typical system has one or more air scoops placed at high points in order to collect the air. The air scoop has a horizontal partition that scoops the air upward and allows the water to flow through. The air is removed by an air release valve.

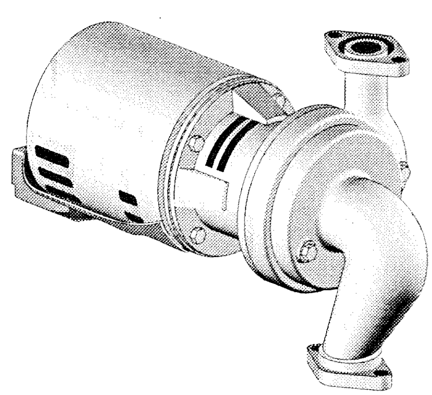


Air Release Valve

An air release is composed of a float and discharge nozzle. When air is accumulated in the valve, the float drops down and allows the air to escape.

Circulation Pump

A end-suction centrifugal pump is used to circulate water in the hydronic loop. The pump is commonly installed to pump into the boiler inlet. There are two common pumps used in rural Alaska, the frame mounted end-suction centrifugal Bell and Gosset and the close coupled end-suction centrifugal by Grundfos. Both pumps have the ability to produce a 10 psi differential pressure between suction and discharge.



Flow Control Valve

Because of the temperature differential between the water coming in and the water going out of a boiler, natural convection will cause the water to circulate even when the circulation pump is shut off. Since the circulation rate is important to the energy transfer rate, it is preferred that this rate be controlled by the circulation pump. A flow control valve placed in the loop prevents the water from circulating except when the pump is operating.

SUPPORT COMPONENTS

Thermometers

Thermometers are placed on the discharge and return lines. The temperature differential is one of the operating data points that is important to collect.

Drip Pan

Because glycol is corrosive, when it is used in a boiler a drip pan is placed under the boiler. The drip pan must be sized large enough to hold all of the fluid in the boiler.

Flame Site Glass

Just above the burner assembly is a small opening directly into the combustion chamber. This opening is covered with heat resistant glass. The opening, known as a flame site glass, is used to observe the presence and color of the flame.

Temp & Pressure Gauges

Each boiler is equipped with dual temperature and pressure gauge. The boiler temperature should remain between 180°F and 200°F all the time it is operating. The boiler pressure should remain between 12 and 15 psi.

High Pressure Blow-off

Pressures above 30 psi can damage the boiler. Therefore, a standard high pressure blow-off is installed directly into one of the boiler sections. The valve is set to discharge water at 30 psi. The discharge is commonly piped into the floor drain.

Flow Indicators

Rotometer type flow indications are installed in hydronic loop to allow the operator to determine that circulation is actually taking place and that there is no circulation when the circulation pump is shut off.

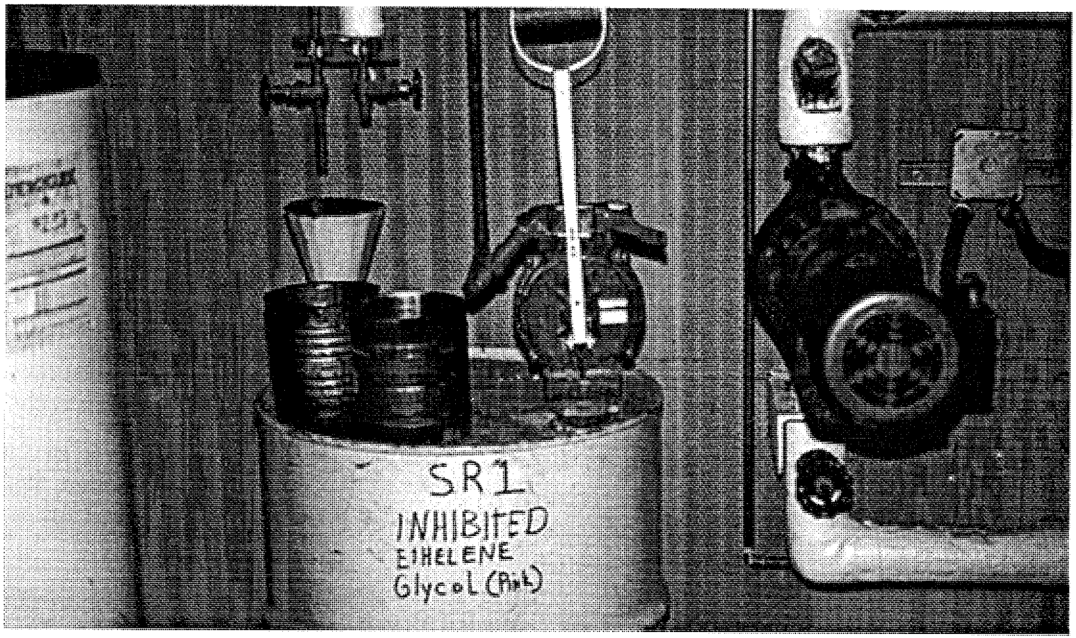
GLYCOL REPLENISHING SYSTEM

Normal Leakage

All piping systems will have some normal leakage. The hydronics system is no different than any other. When leakage occurs from a glycol system, the pressure drops and the circulation rate goes up (With a centrifugal pump, as the TDH goes down flow goes up). This would reduce the efficiency of the system. When the pressure drops as a result of leakage the lost glycol must be replenished.

Other Losses

As a fluid is heated and pumped, gases contained in the fluid will be released. This release will reduce the fluid volume and thus the system pressure.



Components

A typical glycol replenish system starts with a 55 gallon tank and a hand operated rotary pump. The discharge of the pump is connected directly into the glycol piping system. An isolation valve allows the pump to be disconnected. A check valve prevents fluid from flowing from the system into the glycol tank. With all glycol systems, it is important that a drain valve be placed at the low point in the piping system.

Process

When the system pressure drops to 5 psi, glycol should be pumped into the system until the system pressure is brought back to normal.

Aggressive/Corrosive Glycol

As glycol ages it becomes aggressive and will corrode the piping. When the pH reaches 7, the fluid should be replaced.

MAKE-UP WATER SYSTEM

Normal Losses

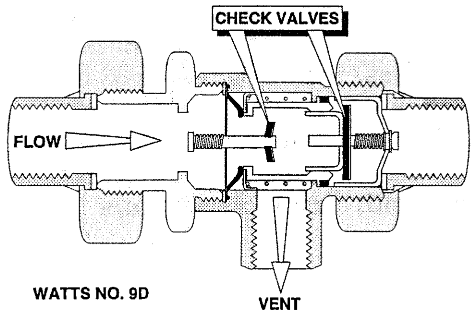
When a system does not use glycol in the hydronic loop, water is the heat carrier. Water will leak from piping just as glycol will. Also gases will escape reducing the waters volume.

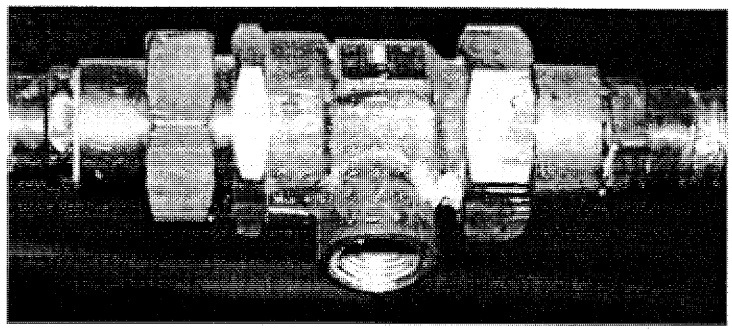
Make-up Water

The water used to replenish these losses is called make-up water. The most common source of make-up water is the potable water system. The hydronics system is isolated from the potable water system by a gate valve.

Backflow Prevention

To prevent backflow from the hydronics system into the potable water system, a backflow prevention device must be installed in this line. A reduced pressure backflow prevention device is placed on the potable water line.



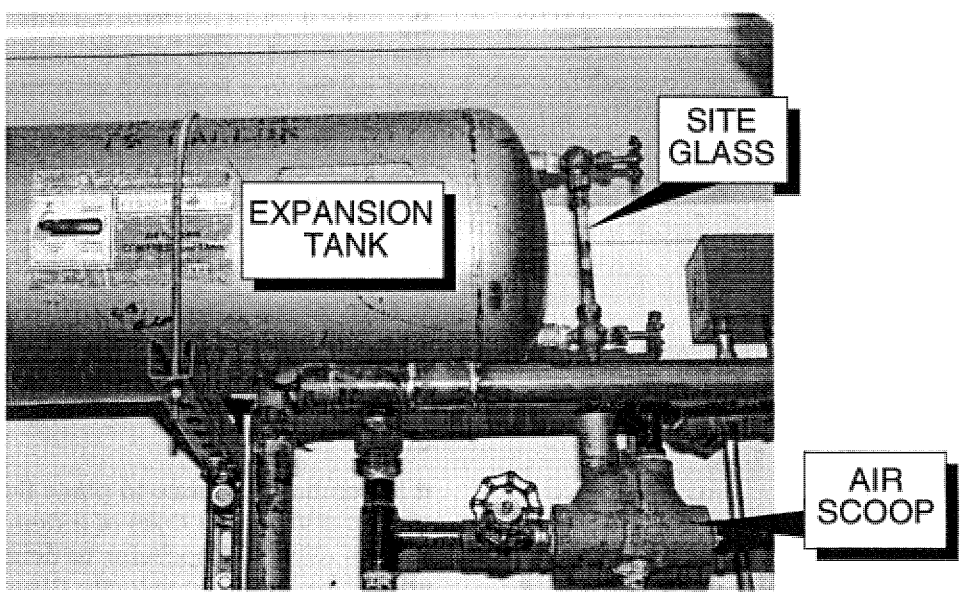


Pressure Reducing

Because the potable water system is usually higher pressure than our hydronic loop, a pressure reducing valve must be installed on the make-up water line.

Expansion Tank

When water is heated it expands. The potable water is usually a lower temperature that the hydronics loop. Therefore, when cold potable water is added and heated the system pressure would go up. To prevent this, an expansion tank is installed on the hydronic loop. The expansion tank will allow the water volume to increase without changing the pressure in the system. The size of this expansion tank is dependent on the volume of the system, a typical expansion tank is a horizontal 15 gallon tank with a site glass on one end. Normally this tank is 60% full of water.



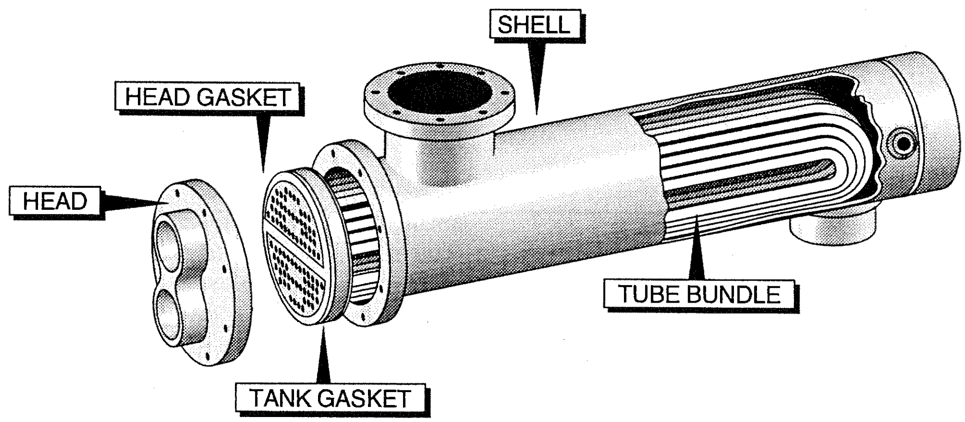
Air release

Since heating water will cause dissolved gases to come out of solution, an air release valve is placed in on the expansion tank.

HEAT EXCHANGER

Process

The last piece of the hydronics system is the heat exchanger. Typical heat exchangers used for this purpose are the shell and tube type. The hydronics loop is pumped through the shell while potable water is pumped through the tubes. Heat is transferred from the hydronics loop to the potable water within the heat exchanger. The latest regulations require that a double wall heat exchanger be used when connecting a potable water source with a nonpotable water source.



POTABLE WATER SYSTEM

Start At Heat Exchanger

Potable water is pumped through the tube portion of the heat exchanger. The potable water flowing through the heat exchanger may be water that is being heated and added to a feed loop or it may be the entire feed loop.

Temperatures

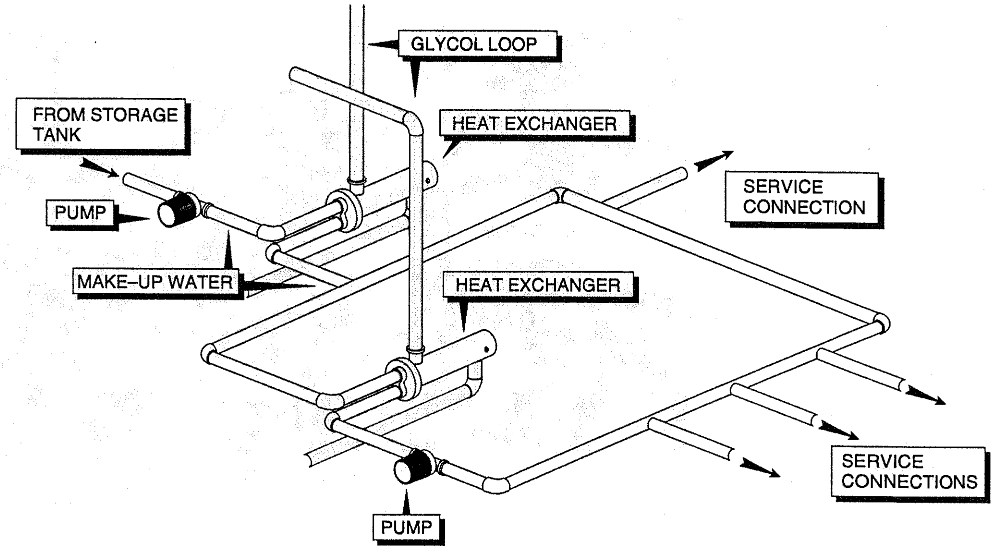
The temperature of the return to the heat exchanger must be above 35°F. The exit temperature must be high enough to maintain this return. Typical exit temperatures range from 40°F to 45 °F.

Pumping

System pressure and velocity are commonly maintained by end-suction centrifugal pumps. These pumps should have suction and discharge pressure gauges in order determine the pumps operating conditions.

Flow meter

It is common practice to place flow meters in the discharge and return lines of a distribution loop. These meters allow the operator to determine the amount of water used and the velocity through the system. When pitorifices are used on the service lines, a velocity above 2 ft/sec must be maintained.



CONTROL SYSTEM

Heart of System

The heart of the low pressure boiler system is the control subsystems. The control systems include the operating electrical subsystem used to fire the boiler, the loss of flame and power control subsystem, the motor protection subsystem and the hydronics control subsystem.

OPERATING CONTROLS

Circuit Breaker

The operating control system starts at the circuit breaker in the control panel. The breaker is provided to protect the plant wiring and building from a short circuit.

On & Off Control

Power in the form of 120 volts is brought from the control panel to an on and off switch located close to the boiler. This switch is a typical household light switch.

Contact Relay

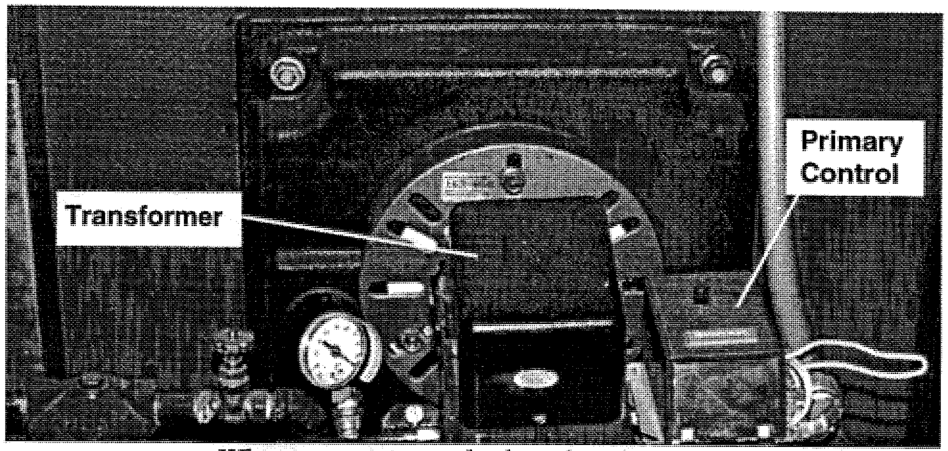
From the power switch, power is connected to three contact relays, one controls the low water cut off switch, the second controls the temperature controls and the third controls the primary control.

Primary Control

The primary control is mounted above the motor on the burner assembly, contains a contact relay and wiring that connect the transformer, CAD cell and fuel solenoid valve together with the temperature control unit.

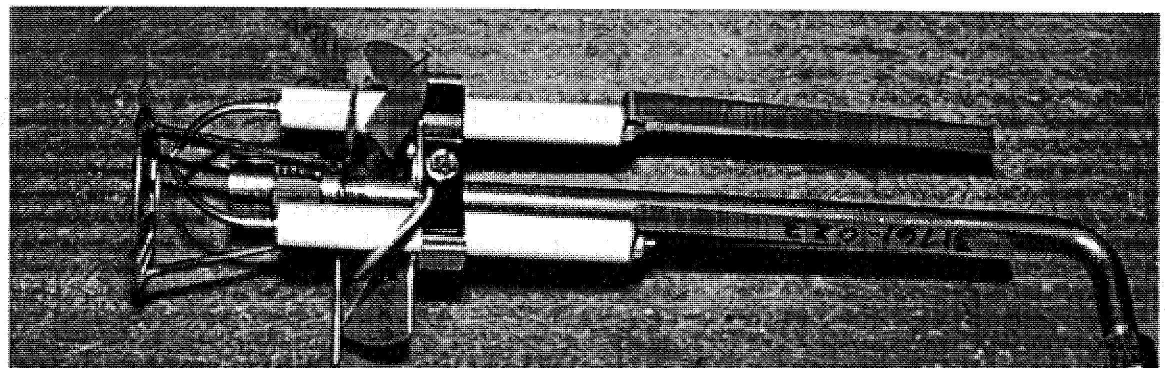
Transformer

From primary control, power is connected to a high voltage transformer that is mounted on top of the burner assembly. This is a step up transformer, stepping up the voltage from 120v to 10,000 volts. While this is a very high voltage, the available amperage is very low, thus reducing the possibility of dangerous electrical shock.



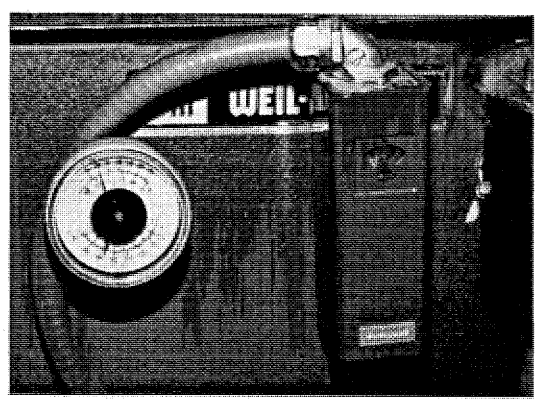
Electrodes

When power is applied to the electrodes, a spark is created that is used to ignite the fuel and start combustion.



Temperature Control

The most common temperature control unit is the Hi-Lo controller. This device usually is attached to the back of the boiler and has an immersion probe that is inserted into the boiler water jacket. The Hi-Lo control works on a differential between two temperatures. This differential is the difference between the burner starting and stopping. Common aquastats used in Alaska are the Honeywell L6006 A or B and the L4006 A or B. Normal temperature ranges for these boilers are on at 170°F and off at 180°F.



Control Circuit Sequence

When the aquastat determines that the water temperature has fallen below the minimum temperature, it closes and energizes the relay in the primary control.

The primary control, in turn, opens the oil supply solenoid, starts the electrical motor and energizes the electrode transformer.

High Temperature

For protection boilers usually have a high temperature cut-off aquastat also installed in the water jacket of the boiler. This aquastat is wired in series with the Hi-Lo aquastat. When the temperature exceeds a set level, the high temperature cut-off aquastat opens its contacts and prevents the boiler from operating. High temperature cut-off is usually set at 210°F to 220°F.

Loss of Power Control

The fuel solenoid valve is normally a closed valve held open when power is applied. As such if there is a loss of power, the valve will close preventing oil from entering and flooding the combustion chamber.

Darkness Control

The flame sensing CAD is located in the burner nozzle and performs two tasks. At start-up the CAD cell must "see darkness" or it will not allow the primary control to send power to the transformer. This prevents fuel from being added to the combustion chamber when a flame already exists. To do so would extinguish the flame. The CAD cell also prevents the burner from being "fired" when the burner assembly has been removed or the combustion chamber is open for some reason. Once power is applied to the electrodes the a time delay relay prevents the CAD cell from switching to the flame detection mode for 3 to 8 seconds.

Loss of Flame Control

Once the boiler is operating and a loss of flame occurs, the CAD cell will, after a set time delay, send a signal to the primary controller to shutdown the solenoid valve, motor and electrode transformer. CAD cells can be purchased with 15, 30 or 45 second time delays. The most common CAD cell is the Honeywell R8184G.

Reset

Once the CAD cell has either prevented start or stopped the operation of the boiler, the "red" reset button on top of the primary controller must be pushed in order for the boiler to restart.

MOTOR PROTECTION CONTROLS

Thermal Overload

The motor on the burner assembly is protected from damage due to an excessively high current draw that persist for 20 to 60 seconds. When a motor has a high current draw heat is produced. This heat is sensed by a bimetallic strip placed in the motor power circuit called a thermal overload. When the thermal overload heats sufficiently, it will bend and physically disconnect power to the motor shutting off the motor. This also disconnects power to the primary control shutting down the burner.

Reset

To reset the thermal overload after tripping, wait until the motor has cooled down and then press the "red" reset button on the side or end of the motor and check the amperage draw of the motor. If the amperage draw exceeds the name plate amperage, replace the motor.

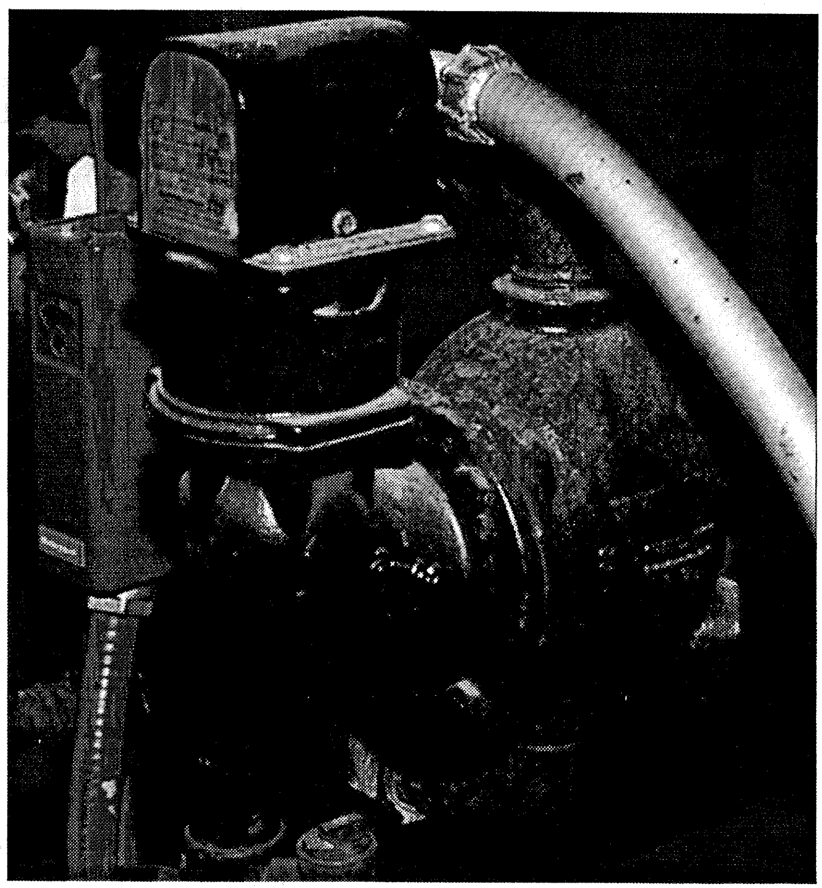
HYDRONICS CONTROL

Low Water Level

The primary control on the hydronics system is the low water level shut-off control. There are two types of low water level shut-off controls used, a float type and a conductivity probe type. Both are placed on the front of the boiler near the top of the water jacket.

Operation - Float

With the float type (usually a McDonald #63), a set of contacts is held closed by a float that is in the boiler water jacket. Should the water level drop sufficiently, the contacts will open. These contacts are wired in series with the primary control. Loss of power will shutdown the boiler.



Conductivity Probe

The conductivity probe (usually a McDonald #900) operates in a very similar way to the float. The only difference is an electrical conductivity probe is placed in the water jacket instead of the float. When there is no water around the probe, conductivity is lost and the circuit supplying power to the primary control is opened.

NORMAL OPERATIONS

Included

Normal operations of a boiler requires routine observations, data collection, inspection, cleaning and repair. In order to resolve typical boiler problems, it is important to have a basic understanding the process of combustion.

THEORY

Fuel

The fuel used by the low pressure boilers discussed here is #1 Arctic grade diesel, that will maintain flow at temperatures down to minus forty degrees Fahrenheit (-40°F).

COMBUSTION PROCESS

Function

The reason for burning a fuel is to get it to release heat. Heat is measured as **BTU's**[16]. A BTU is the amount of energy required to raise the temperature of one pound of water one degree Fahrenheit.

Heat From Oil

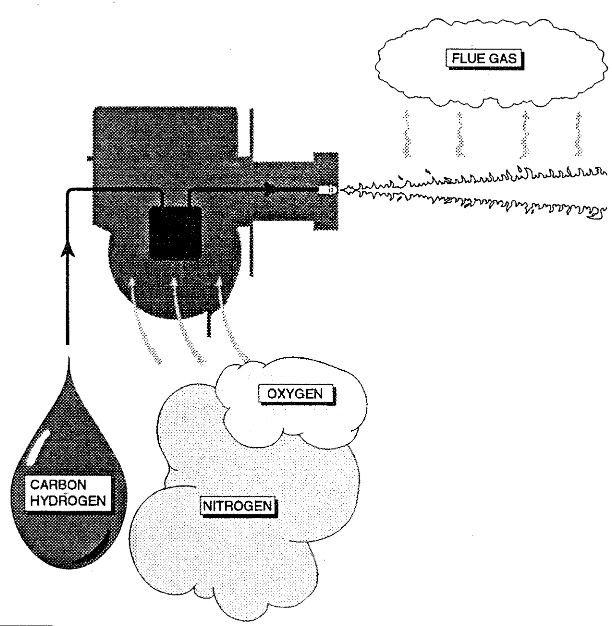
Number one diesel, when fully combusted will release 136,000 BTU's per gallon (#2 is 140,000 BTU's per gallon). We will use this heat source to heat the water or glycol in the boiler.

Components

Combustion with oil is a result of mixing the oil, which is hydrogen (H) and carbon (C), with the oxygen (O) in the air. Air is basically 79% nitrogen (N) and 21% oxygen (O). Only the oxygen portion of the air becomes involved in the combustion process.

Complete Combustion

When oxygen (O), carbon (C) and hydrogen (H) are mixed together in the proper quantities and ignited, complete combustion will result. The end product will be heat, water (H_2O) and carbon dioxide (CO_2).



[16] **BTU** - British Thermal Unit. The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

Incomplete Combustion

When incomplete combustion occurs, the results are the production of water, carbon dioxide, aldehyde and carbon monoxide. Aldehyde and carbon monoxide are both poisonous gases.

Vaporizing Oil

Oil as a liquid will not burn. In order for it to burn, it must vaporize. The function of the nozzle is to break the oil into billions of tiny droplets that will then easily vaporize. For instance a 0.5 gallon per hour nozzle will produce about 40,000,000,000 droplets of fuel each hour. The process of turning oil into droplets is called atomizing the oil.

CONTROLLING COMBUSTION

Air Supply

One of the keys to proper combustion is controlling the air to fuel ratio. For proper combustion, one gallon of fuel will require 100 pounds of air (approximately 14,000 to 18,000 cubic feet). One of the keys to combustion is to control the air supply. Not enough air will produce excessive aldehyde and carbon monoxide. Excessive amounts of air will produce low carbon dioxide and high stack temperature. Fast movement of gases through the combustion chamber will produce low efficiency. The amount of air is controlled by the air intake on the burner assembly. The adjustment of air supply is described in the section on "Routine Testing and Inspections."

Oil

Another important key to proper combustion is having the oil under the correct pressure so that droplets of the correct size are produced and the oil is sprayed in the correct pattern for the type of burner nozzle used.

Spark

The final key to proper combustion is a sufficiently "hot" spark to ignite the fuel air mixture. This requires having the correct voltage on the electrodes and the electrodes being properly spaced and positioned in relationship to the fuel being sprayed from the nozzle.

EFFICIENCY

Gases

As air is forced though the combustion chamber, only the oxygen becomes involved in the combustion process. The nitrogen and other inert gases, which make up 79% of the air, are heated from room temperature to the temperature of the stack (375°F to 550°F) and exit out the stack. These gases are heated by the fuel and then they exit the stack taking heat with them. This is a loss of energy.

Transfer

When you are standing next to a boiler you know that it is hot, even with out touching it. The boiler is simply heating the air. While this may be nice in the winter, it is a loss of heat. All heat that is not transferred directly from the fuel to the fluid in the hydronic system is a loss.

Desirable Level

It is not possible to have a low pressure, oil fired boiler with a efficiency greater than 90%. In fact an efficiency of 81% to 84% is considered excellent. When the efficiency is below 78% the boiler fuel and air system should be serviced.

Impact of Low efficiency

One small community of 300 people used 16,000 gallons of fuel at $3.10 a gallon to heat the water in the distribution system. This is a total cost of:

16,000 gal X $3.10 per gal = $49,600

If the efficiency of the boiler system could be improved by 5%, the savings would be:

Assume that 5% less fuel is used.

0.05 X 16,000 gal = 800 gal not used.

800 gal X $3.10 per gal = $2,400 savings.

EFFICIENT OPERATIONS

Introduction

Efficient operation requires the best combustion and heat transfer in the boiler and the best heat transfer in the heat exchanger. The following are general guidelines that may be helpful in balancing your system.

Differential Temperatures

Generally we want to minimized the difference between the temperature in and out of a heat exchanger and boiler. The closer the differential, the less amount of heat required to return the temperature to the desired level. For instance, to raise water from 35°F to 40°F requires far less energy than to raise the water from 35°F to 45°F.

Flow Rate

As was indicated earlier, the flow rate on a loop system using pitorifices must be above 2 feet per second. The following is a short table to help you relate flow in gpm to velocity.

Pipe Size	**Flow necessary for 2 ft/sec**
2"	20 gpm
3"	44 gpm
4"	78 gpm
6"	176 gpm

Flow Rate & Heat Transfer

The higher the flow rate, the shorter the time allowed for heat to transfer inside of the heat exchanger. One of the difficulties in the design of this type of system is to balance the heat requirements with the flow rate.

Boiler Operation

What is desirable is to balance the air supply into the combustion chamber with the fuel supply. If the air supply is too high, the combustion process will be pushed to the back end of the combustion chamber and up the stack. This would be noticed with higher than normal stack temperatures. If the combustion is incomplete so that uncombusted fuel is going up the stack, you will observe smoke and cold stack temperatures and a drop is CO_2.

CO_2 & Stack Temperature

For proper operation, the stack temperature should remain between 375°F and 550°F with a CO_2 reading between 10% and 14%.

Smoke and Draft

The amount of smoke as indicated by a smoke test should be between zero and a trace and the draft should be 0.02" Hg.

ROUTINE INSPECTION AND TESTING

INSPECTION

For efficient and safe operation of a low pressure boiler system, the following items should be inspected at the frequency noted:

Daily

Daily observe and record the following

- Boiler pressure
- Boiler temperatures
- Heat exchanger temperatures
- Smoke stack exhaust appearance
- Flame appearance, size and shape

Weekly

Once a week observe and record the following:

- Inspect the fuel system for leaks
- Perform a burner shutdown. At shutdown the flame should not last more than 2 seconds and should not become smoky

TESTING

Test Kit Required

The best test kit for use with a low pressure oil fired boiler is the Bacharach Kit #10-5022. This kit contains the following items:

- Fyrit® CO_2 indicator
- Smoke Tester and oil burner smoke scale
- Fire efficiency finder
- Stack thermometer
- MZF draft gauge
- Drafite® draft gauge

TESTING FREQUENCY

Each Month

Once each month you should perform the following test and record the results.

- Stack Temperature - PHS material says daily
- Smoke test - PHS material says weekly

• CO_2 level

Annual

Once each year, just after the burner and boiler have been rebuilt, test the draft along with smoke, stack temperature and CO_2 level.

Desired Ranges

The desirable ranges for each of these test are:

• Draft - should be 0.02" Hg

• Smoke - 0 to trace

• CO_2 - levels depend on manufacturer, usually 10% to 14%

• Stack Temperature - proper levels are 375°F to 550°F

CONDUCTING A SMOKE TEST

Description

A smoke test is performed with an instrument that draws a set amount of air from the stack. The air is filtered through a paper. The smoke is collected on the paper and the results compared to a standard scale.

Procedure

1. Place a clean piece of standard-grad filter paper into the holding slot of the smoke tester and tighten the locking nut.
2. With the burner running and the stack temperature at normal, place the sampling tube end of the tester in the 1/4 inch hole in the flue.
3. Pull the smoke tester handle thorough 10 full pump strokes. Once the handle is pulled full back, wait several seconds before completing the next cycle.
4. Remove the tester from the stack.
5. Loosen the filter locking nut and remove the filter paper.
6. Compare the results with the smoke scale indicator.

SCALE INDICATOR RESULTS

Reading	Condition
1	Excellent - Little if any sooting of boiler surfaces.
2	Good - May be slight sooting of boiler, but little if any increase in flue-gas temperature.
3	Fair - Substantial sooting with some types of boilers. but rarely will require cleaning more than once a year.
4	Poor - This is a borderline smoke. Some units may soot only moderately, but others may soot rapidly.
5	Very poor - Heavy sooting in all cases. May require cleaning several times during the heating season.

ROUTINE MAINTENANCE

Weekly

Once each week test the operation of the following:

- All safety equipment operation
- Check limit controls

Six Month

Every six months perform the following:

- Lubricate motor bearings
- Check adjustment of electrode
- Clean gun-tube assembly

Annual

Once each year the following maintenance should be performed. It is most desirable that this maintenance be completed directly after the heating season. This will give an opportunity to obtain parts and materials should, during the maintenance, you find major parts damaged.

- Remove the burner assembly, and clean-out plates. Clean soot from between boiler sections and use a vacuum cleaner to clean the combustion chamber.
- Examine the stack and chimney for cleanliness and tight joints (use a mirror). Clean the stack and chimney if necessary.
- Replace all fuel filters.
- Repair all fuel line leaks.
- Replace the nozzle.
- Replace electrode insulators if cracked.
- Check burner operation.
- Check nozzle oil pressure.
- Perform combustion test and smoke test.
- Check fuses for size and electrical connections for tightness.
- Clean and or replace air intake filter - as necessary.

WINTERIZATION

Activities

In preparing the boiler for winter, perform all of the annual and semi-annual testing and maintenance described above. Besides these activities, test the specific gravity and pH of the glycol. Glycol becomes aggressive with age and can cause considerable damage to the pumps and piping. Glycol should be removed when the pH reaches 7.0.

TYPICAL PROBLEMS

Problem	Initial Check
Cold Building, cold boiler	Check on/off switch Check for power to burner No power, check circuit breaker or fuses

Result of Initial Check	Secondary Actions or Checks
1. Power at boiler but burner off	• Try reset on control box. If burner runs, stop burner immediately and check for excess oil in chamber
2. Burner runs, flame goes on and off	• Check fuel supply, filters, pump strainer, for broken coupler, water in oil, or low pump pressure • Check nozzle for dirty screen • Broken pump coupler
3. Burner lights after	• Check nozzle and fuel system for dirt and water • Check ignition transformer for weak spark • Check for cracked porcelains, electrode adjustment
4. Burner runs smoky	• Check for excess soot and clean boiler • Check nozzle, fuel system, for water, dirt • Check burner fan and air shutter for dirt • Check pump coupler for slipping • Check pump pressure • Check air adjustment, nozzle condition and gap on electrodes
5. Burner runs but stops after 15, 30 or 45 seconds	• Check CAD cell for dirt • Can the CAD cell see the flame where it is mounted • Check for too much air, flame too small for cell to see, plugged nozzle • Replace with new cell • Replace cell holder and leads • Replace control
6. Burner lights hard, puff back	• Check for too much air, adjust air shutter • Check for weak ignition transformer • Check for bad porcelains, electrode adjustment
7. Burner off, pump has to be bled	• Check fuel level in storage tank • Check for leaking check valves • Other burners on same fuel line taking oil from this unit • Leak in fittings, sucking air • Check pump vacuum - should be 29 " of Hg • Pinched oil line, stopping flow • Plugged fuel filter • Closed fuel valve in line • Plugged vent causing excessive vacuum

Problem	Initial Check
Cold Building Hot Boiler	• Check circulating pump for running • Check boiler pressure, air in system • Check circulating pump coupler, pump motor running but coupler broken • Check thermostat control • Check boiler temperature, can burner keep up in severe cold • Check for dirty coils in fan coil units • Check for drafts around doors and windows and seal as needed • Check for fan motor running in fan coil units, is fan dirty • Check for dirty boiler and excess stack temp

INTRO. TO LOW PRESSURE BOILERS WORKSHEET

1. Low pressure boilers means boilers with pressure that does not exceed...

   _______ a. 10 psi

   _______ b. 50 psi

   _______ c. 30 psi

   _______ d. 45 psi

   _______ e. 150 psi

2. The typical tank in a fuel farm is _________ gallon.

   _______ a. 300

   _______ b. 8000

   _______ c. 500

   _______ d. 1000

   _______ e. 10,000

3. The fuel used in low pressure boilers in Alaska is ...

   _______ a. #1 Arctic grade diesel

   _______ b. #2 Arctic grade diesel

   _______ c. #1 Arctic grade kerosene

   _______ d. #2 Bunker fuel

   _______ e. #1 Bunker fuel

4. If the site fuel storage tank is with in 100 feet of the potable water well, then what is the maximum number of gallons the tank can hold?

   _______ a. 50

   _______ b. 250

   _______ c. 300

   _______ d. 500

   _______ e. 1000

5. A day tank usually holds between ______ and ______ gallons.

   _______ a. 300 and 500

   _______ b. 5 and 55

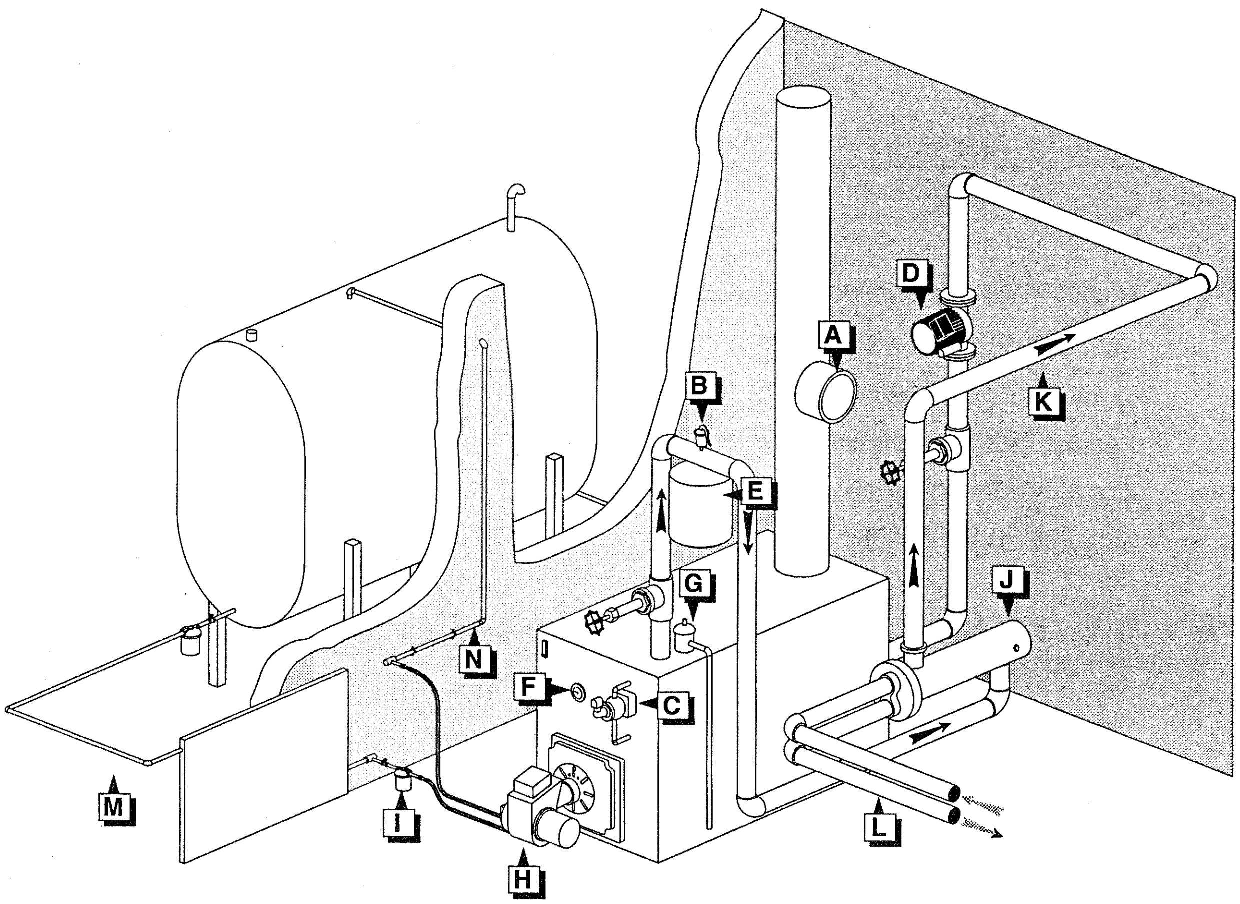
   _______ c. 10 and 20

   _______ d. 25 and 42

   _______ e. 100 and 250

6. Identify the boiler system components identified below

_______ Expansion Tank
_______ Pressure relief valve
_______ Burner
_______ Temp. and pressure gauge
_______ Oil filter
_______ Oil supply
_______ Water loop
_______ Glycol loop
_________ Circulating Pump
_________ Fuel return line
_________Low water cut-off
_________ Barometric damper
_________ Air release valve
_________ Heat exchanger
_________ Oil return line



7. The fusible valve used on a boiler fuel supply line is designed to close anytime the room temperature exceeds _________.

_______ a. 220°F
_______ b. 180°F
_______ c. 45°F
_______ d. 140°F
_______ e. 35°F

8. Fuel filter should be changed at least every ___________.

_______ a. Year

_______ b. Four months

_______ c. Quarter

_______ d. Month

_______ e. Week

9. The discharge pressure of the burner fuel pump must be at least _________ psi.

_______ a. 10 psi

_______ b. 50 psi

_______ c. 200 psi

_______ d. 30 psi

_______ e.100 psi

10. What does the designation 0.5 g/h on a burner nozzle mean.

_______ a. 0.5 grains per hour - the weight of the fuel discharged from the nozzle

_______ b. It is a manufacturing designation for the size of the opening

_______ c. Gallons per hour

_______ d. A spray that is at 45 degrees

_______ e. A hollow spray covering 50% of the area with oil

11. The CAD cell is used for what?

_______ a. Sense the presence or absence of light

_______ b. Shut off the burner after 15 seconds if the heat is too intense

_______ c. Shut off the burner only after there has been a flame for 30 seconds

_______ d. Protects the motor from an overload condition

_______ e. Protects the primary control from a high current draw

12. What is the name of the device used to control a draft through the combustion chamber?

_______ a. Squirrel cage fan

_______ b. Electric motor

_______ c. Barometric damper

_______ d. Draft control

_______ e. Air flow control chamber

13. When glycol and water are mixed in the hydronic system, what is the most common mix.

_______ a. 10 to 50

_______ b. 5 to 55

_______ c. 50 to 1

_______ d. 50 to 50

_______ e. 20 to 40

14. Identify the components of the burner assembly shown below.

_______ Pump

_______ Blast tube

_______ Nozzle

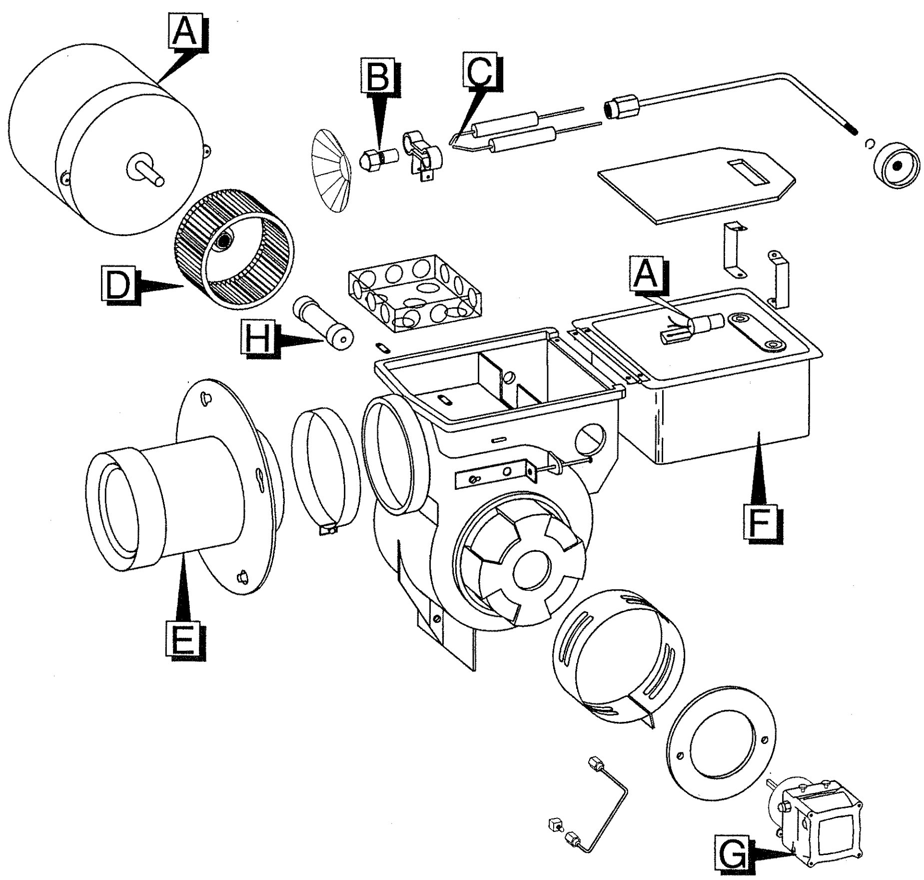
_______ Fan

_________ Transformer

_________ Motor

_________Coupling

_________ Electrodes



15. The fluid loop between the boiler and the heat exchanger should pass through which portion of the heat exchanger?

_______ a. Tubes

_______ b. Shell

16. When an air expansion chamber is placed on a hydronic loop there are two devices commonly installed above the chamber, they are:

_______ a. Flow control valve

_______ b. Air scoop

_______ c. Circulation pump

_______ d. Thermometer

_______ e. Air release valve

17. The operating temperature of a low pressure boiler normally ranges between what two temperatures?

_______ a. 35 °F & 45 °F

_______ b. 100 °F & 150 °F

_______ c. 212 °F & 220 °F

_______ d. 180 °F & 200 °F

_______ e. 300 °F & 350°F

18. The operating pressure on a low pressure boiler normally ranges between what two levels?

_______ a 12 & 15 psi

_______ b. 20 & 30 psi

_______ c. 35 & 45 psi

_______ d. 55 & 85 psi

_______ e. 45 & 90 psi

19. The high pressure blow-off on a low pressure boiler is set to exhaust at _______ psi.

_______ a. 10 psi

_______ b. 45 psi

_______ c. 20 psi

_______ d. 100 psi

_______ e. 30 psi

20. The appropriate protection on a potable water make-up water line to a low pressure boiler is a:

_______ a. Atmospheric vacuum breaker

_______ b. Check valve

_______ c. Double check valve assembly

_______ d. RPZ

_______ e. Air gap

21. The return temperature on a heated circulation loop should not drop below ________°F.

_______ a. 10° F

_______ b. 55° F

_______ c. 30° F

_______ d. 45° F

_______ e. 35° F

22. The exit temperature from the potable water side of a heat exchanger, exiting into a circulation loop should range between what two temperatures?

_______ a. 35°F & 38°F

_______ b. 40°F & 45°F

_______ c. 45°F & 55°F

_______ d. 180°F & 200°F

_______ e. 140°F & 180°F

23. The high temperature cut off is designed to shutdown the boiler system anytime the temperature of the fluid in the boiler exceeds what temperature.

_______ a. 180°F to 200 °F

_______ b. 300°F to 35 °F

_______ c. 140°F to 160 °F

_______ d. 200°F to 220 °F

_______ e. 190°F to 212° F

24. When oil is properly completely burnt in a combustion process, what two by products are produce?

_______ a. Aldehyde

_______ b. Water

_______ c. Carbon monoxide

_______ d. Carbon

_______ e. Carbon dioxide

25. There are three key items that must be controlled in order to control combustion, they are oil, spark and __________.

_______ a. Pressure

_______ b. Temperature

_______ c. Pump velocity

_______ d. Fuel flow rate

_______ e. Air

26. A properly operating boiler should not have a stack temperature above _________°F.

_______ a. 150° F

_______ b. 350° F

_______ c. 550° F

_______ d. 800° F

_______ e. 212° F

27. When a burner is operating properly the CO_2 level will be ___________.

_______ a. 1 to 5%

_______ b. 89 to 90%

_______ c. 20 to 25%

_______ d. 10 to 14%

_______ e. 15 to 45%

28. The most desirable smoke test reading for a properly operating burner would be..

_______ a. 4 to 5

_______ b. 8 to 9

_______ c. 1 to 2

_______ d. 0 to 1

_______ e. 2 to 3

29. When the pH of glycol reaches ______ it should be removed.

_______ a. 5

_______ b. 9

_______ c. 2

_______ d. 7

_______ e. 6