LOW PRESSURE HEATING BOILERS
BASIC FUNDAMENTALS AND BELL SYSTEM STANDARDS

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1. GENERAL

1.01 This section covers general descriptions, terminology and basic fundamentals of low pressure heating boilers, automatic fuel burning apparatus, and associated equipment. Also included are the recommended standards for combustion, operating, and limit and safety controls for heating systems installed in Telephone Company buildings as covered in the engineering letters and memoranda E.L. 72, E.M. 485, P.E.L. 7130, P.E.L 7131, and P.E.L. 7211.

1.02 Since this is a general revision, arrows ordinarily used to indicate changes have been omitted.

1.03 The illustrations used in this section have been selected to show typical examples of the equipment referred to in the text and are not intended to endorse or recommend any one manufacturer's product; nor are the illustrations intended to be used as design criteria or as examples of preferred configuration of equipment.

1.04 For detailed information on any specific unit, the manufacturer's literature should be consulted. Also suggested as additional reading is the reference material listed in Part 10.

1.05 More detailed information on maintenance and operation is to be found in Section 770-210-301 (Hot-Water Boilers), and Section 770-210-302 (Steam Boilers). Section 770-230-303 covers water treatment for low-pressure heating boilers.

1.06 The boilers discussed in this section will be generally divided into two groups, ***Cast-Iron Boilers and Steel Boilers.***

1.07 ***The ASME Boiler and Pressure Code, Section IV defines low-pressure boilers*** as follows:

(a) ***Steam Boilers*** designed for operation at pressures not exceeding 15 psi.

(b) ***Hot-Water Boilers*** designed to be operated at pressures not exceeding 160 psi and temperatures not exceeding 250°F.

Most ***hot-water boilers*** in telephone buildings are designed for a working pressure of 30 psi. As stated previously, ***hot-water boilers*** are available for higher working pressures but they must be designed, tested, and stamped for the higher pressure.

2. GLOSSARY OF TERMS

Boiler Heating Surface: The area of the heat transmitting surfaces in contact with the water (or steam) in the boiler on one side and the fire or hot gases on the other.

Boiler Horsepower: The equivalent evaporation of 34.5 lbs of water per hour at 212°F to steam at 212°F. This is equal to a heat output of 33,475 Btu per hour, which is equal to approximately 140 sq ft of steam radiation (EDR).

British Thermal Unit (Btu): The quantity of heat required to raise the temperature of 1 lb of water 1°F.

Combustion Chamber: That portion of a plant within which combustion occurs. In some cases this is also referred to as the firebox.

Condensate: In steam heating, the water formed by cooling and condensing steam.

Conduction (Thermal): The transmission of heat through and by means of matter.

Conductor (Thermal): A material capable of readily transmitting heat by means of conduction.

Control, Limit: A control responsive to changes in pressure, temperature, or liquid level; to be used for limiting the operation of the controlled equipment.

Control, Operating, Modulating: A device used to initiate operation of the burner or to control modulation of fuel and water on demands of variations in temperature, pressure, water level, time, or other influence.

Controls, Combustion: A system of controls that assure safe starting and operation of the burner.

Control, Safety: An automatic device which is intended to prevent unsafe operation of the controlled equipment.

Convection: The transmission of heat by the circulation (either natural or forced) of a liquid or a gas such as air. If natural, it is caused by the difference in density of hotter and colder fluid.

Cooling Leg: A length of uninsulated pipe through which the condensate flows to a trap and which has sufficient cooling surface to permit the condensate to dissipate enough heat to prevent flashing when the trap opens. In the case of a thermostatic trap a cooling leg may be necessary to permit the condensate to drop a sufficient amount in temperature to permit the trap to open.

Dry-back: A type of boiler construction in which the rear combustion chamber is refractory lined. A term generally applied to Scotch type boilers.

Equipment Ground: A separate metallic connection to ground electrical equipment enclosures and conductor enclosures. The grounding connection is made at the main central office ground connection. The equipment ground "Green Wire" concept is covered in detail in Section 802-001-180.

Feed Water: Condensate returned to the boiler plus make-up water.

Flash Point (Oil): The lowest temperature at which the fuel oil gives off vapors that will ignite when a small flame is passed over the surface of the oil.

Furnace: That portion of a heating plant which includes the combustion chamber and flue up to the first plane of entry into the tubes or secondary heat exchange area.

Gas Appliance Pressure Regulator: A pressure balancing device which will maintain the gas pressure to a burner within ± 10 percent of the operating pressure at any given rate from maximum to minimum firing rates, with variations in inlet pressure not exceeding ± 40 percent of the rated inlet pressure.

Gauge Pressure: The pressure above that of the atmosphere. It is the pressure indicated on an ordinary pressure gauge. It is expressed as a unit pressure such as lbs per sq in. gauge.

Hartford Loop: An arrangement of the return pipe in the form of a loop so that the water in each boiler cannot be forced out below the safe water level. Fig. 1 shows the arrangement and is intended to indicate that the horizontal piping on the right side of the figure is to be located at an elevation that will place the bottom of the inside of the piping at the same relative height as the Lowest Safe Water Level in the boiler.

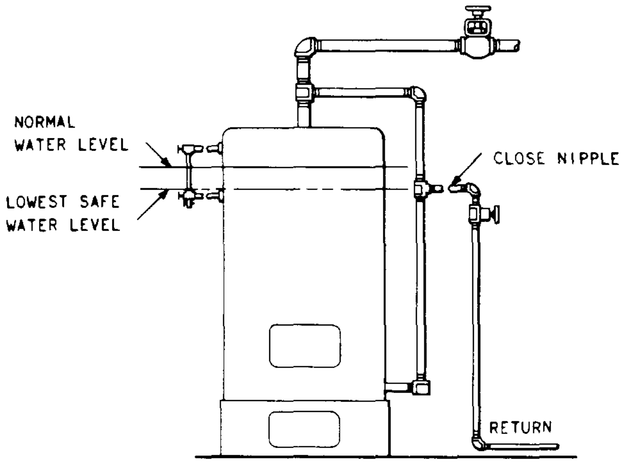


Fig. 1—Hartford Loop

Heat: That form of energy into which all other forms may be changed. Heat always flows from a body of higher temperature to a body of lower temperature.

Heating Value: Amount of heat energy (Btu) released when a pound of fuel is burned.

Lay-up Period: A period when the boiler has been shut down for seasonal or routine maintenance, repairs, or alterations or for other similar reasons.

Make-up Water: Water added from outside the boiler water system to the condensate.

MBh: 1000 Btu per hour.

Modulation: Changing the firing rate in small increments to balance the firing rate with the load to maintain operation between set limits.

Mud Ring (Mud Leg): The bottom of the water leg or other area of a boiler designed to collect dirt or other foreign matter for removal by blowdown.

Pilot, Constant (Standing): A pilot that burns continuously regardless of whether the main burner is off or on.

Pilot, Intermittent: A pilot that is normally electric spark ignited each time there is a call for heat, and burns without turndown the entire time the main burner is firing.

Pilot, Interrupted: A pilot that is electrically ignited automatically each time there is a call for heat and is cut off automatically at the end of the trial-for-ignition period of the main burner.

Pilot, Proved: A pilot that has been proved by a flame detection device.

Pour Point: The minimum temperature at which fuel oil can be pumped or readily flows.

Radiation (Thermal): The transmission of heat in a straight line through space.

SSU: Saybolt Seconds Universal—A measure of oil viscosity at 100°F. The higher the number, the greater the resistance to flow.

Square Foot of Heating Surface (Equivalent), or Equivalent Direct Radiation (EDR): By definition, that amount of heating surface which will give off 240 Btu per hour when filled with a heating medium at 215°F and surrounded by air at 70°F. The equivalent square foot of heating surface may have no direct relation to the actual surface area.

Thermostat: An instrument which responds to changes in temperature and which directly or indirectly controls the temperature of a medium.

Viscosity: Measure of flowability at a definite temperature. It is measured in the number of seconds it takes a given amount of the oil to pass through a certain opening (orifice) at 100°F. High viscosity oil requires special treatment (preheating).

Wet-back: A type of boiler construction in which the rear combustion chamber is water jacketed—a term generally applied to Scotch type boilers.

3. CAST-IRON BOILERS

3.01 Cast-iron boilers are divided into two general classifications:

(1) Round boilers with horizontal or pancake sections, normally limited to very small buildings or locations requiring a maximum heating capacity of approximately 500 MBh gross output.

(2) Square or rectangular boilers with vertical sections, used for any application up to capacities of approximately 13,000 MBh gross output. Most of these boilers are of the internal push-nipple type, but some are constructed with external headers and screw nipples.

Round Cast-Iron Boilers

3.02 Round cast-iron boilers are made up of horizontal sections stacked like pancakes. These boilers have a good reputation for economy and dependability. The trend in smaller telephone buildings, however, has been toward heating systems of a type requiring less maintenance, eg, hot-air systems and electric heating. As a result, the round boiler is not often used in Bell System buildings.

Sectional Cast-iron Boilers

3.03 Sectional cast-iron boilers are square or rectangular in shape and have vertical sections stacked like slices in a loaf of bread. The sectional boiler can be expanded or enlarged by adding sections. The heating surface of this type boiler is large in comparison to its water volume, and it has excellent steaming, internal water circulation and efficiency characteristics. Cast-iron boilers require less maintenance than steel boilers and can be expected to give good service for many years.

3.04 There are two basic types of sectional boilers, the ***internal push-nipple type,*** which is the type most commonly used for telephone buildings, and the ***external header or drum type,*** which utilizes screw nipples.

3.05 The sections of ***internal push-nipple*** boilers are joined with tapered nipples and pulled tightly together with tie rods or bolts (see Fig. 2). These tie rods are not necessary to hold the boiler together. The tapered design and the ground surfaces of the nipples and the openings into which they fit are such that when the sections are drawn together with the tie rods the joints will remain tight even though the rods are removed. They are left in the boiler merely for convenience in reassembling the sections in case repairs at a later date require their use.

3.06 Internal push-nipple boilers designed exclusively for gas fuel (Fig. 3) are constructed with minimum sized combustion chambers. These, along with studs cast into the sections, provide for a maximum of heat absorbing surface.

3.07 ***External header or drum*** (manifold) type boilers (Fig. 4) have the sections individually connected to the header drums (manifolds) with screw nipples. A common arrangement is a steam drum at the top, with two return drums at the bottom, one on each side. Individual sections may be disconnected and replaced without disturbing the rest of the assembly.

4. STEEL BOILERS—FIRETUBE TYPE

4.01 Steel boilers can be generally divided into two types: firetube and watertube. In the firetube boiler the gases of combustion pass through the tubes and the water circulates around them. In a watertube boiler the gases circulate around the tubes and water is contained in the tubes. Most low-pressure, steel, heating boilers are of the firetube type; therefore, the discussion here will be limited to that type.

4.02 Capacities of steel firetube boilers range from those required for small buildings up to about 26,000 MBh output. This type boiler has a large water storage capacity giving it the ability to dampen the effect of wide and sudden fluctuations in steam demand. It offers favorable manufacturing cost and is well adapted to standardization. As a result, the firetube boiler is widely used for heating systems. It is limited to applications where the demands for steam are relatively small as compared to those of large power station installations that use watertube boilers. Firetube steel boilers can be further classified as external furnace and internal furnace.

EXTERNAL FURNACE BOILERS

4.03 In this type boiler the external furnace, which may be brick set or steel jacketed,

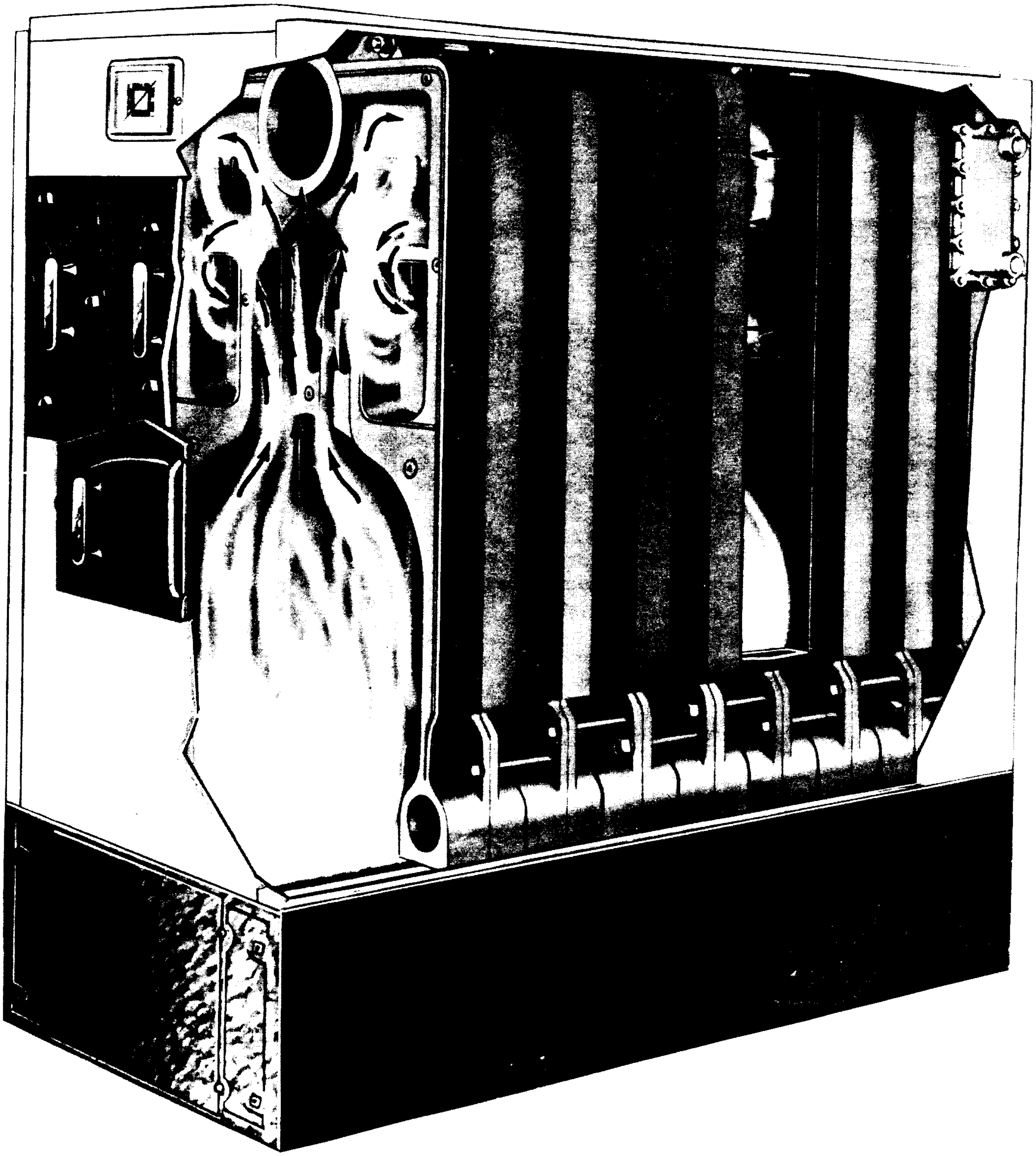


Fig. 2—Internal Push-Nipple Boiler (H. B. Smith Co., Inc.)

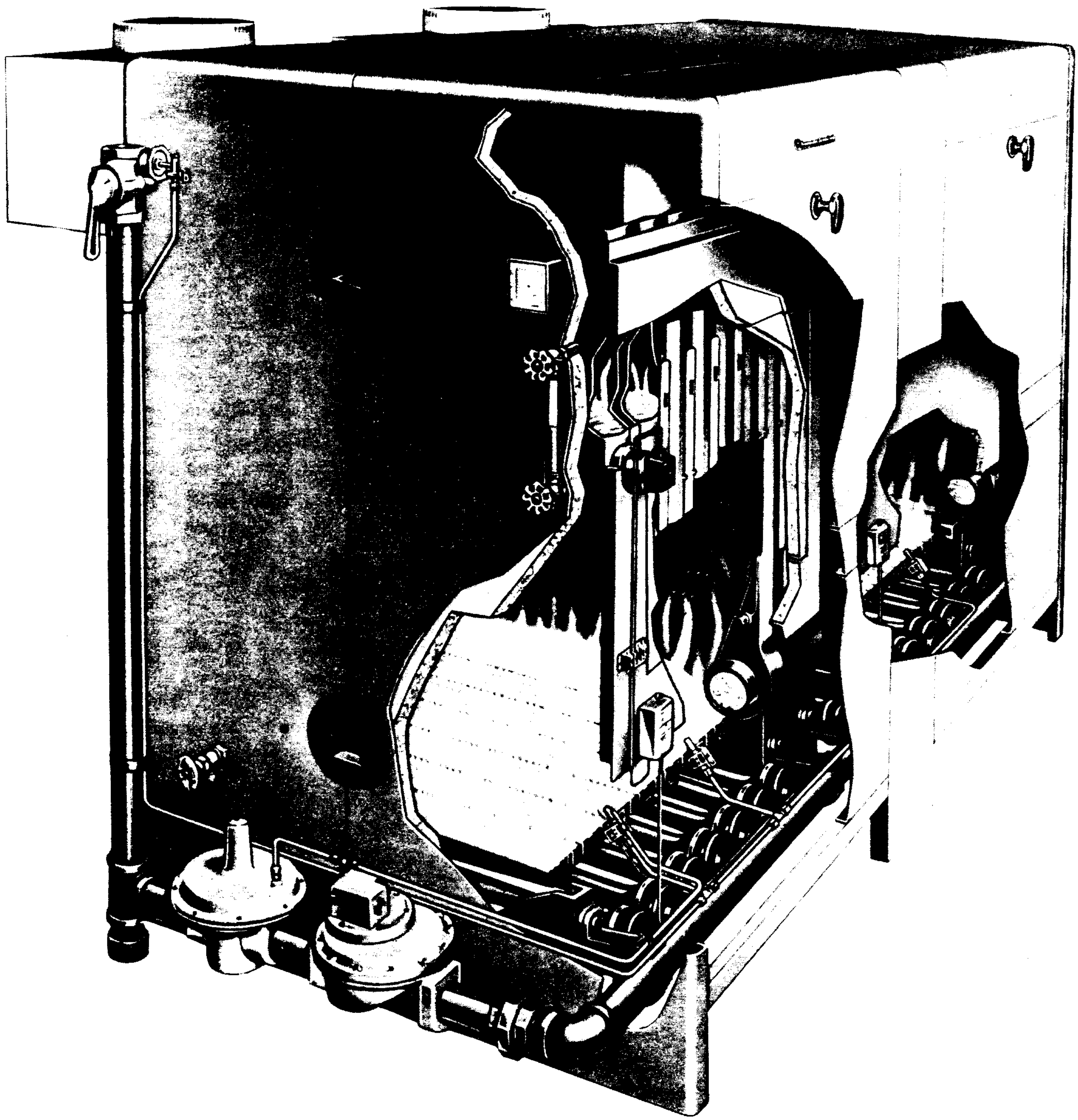


Fig. 3—Cast-Iron Boiler Designed Exclusively For Gas Fuel (American Radiator and Standard Sanitary Corporation)

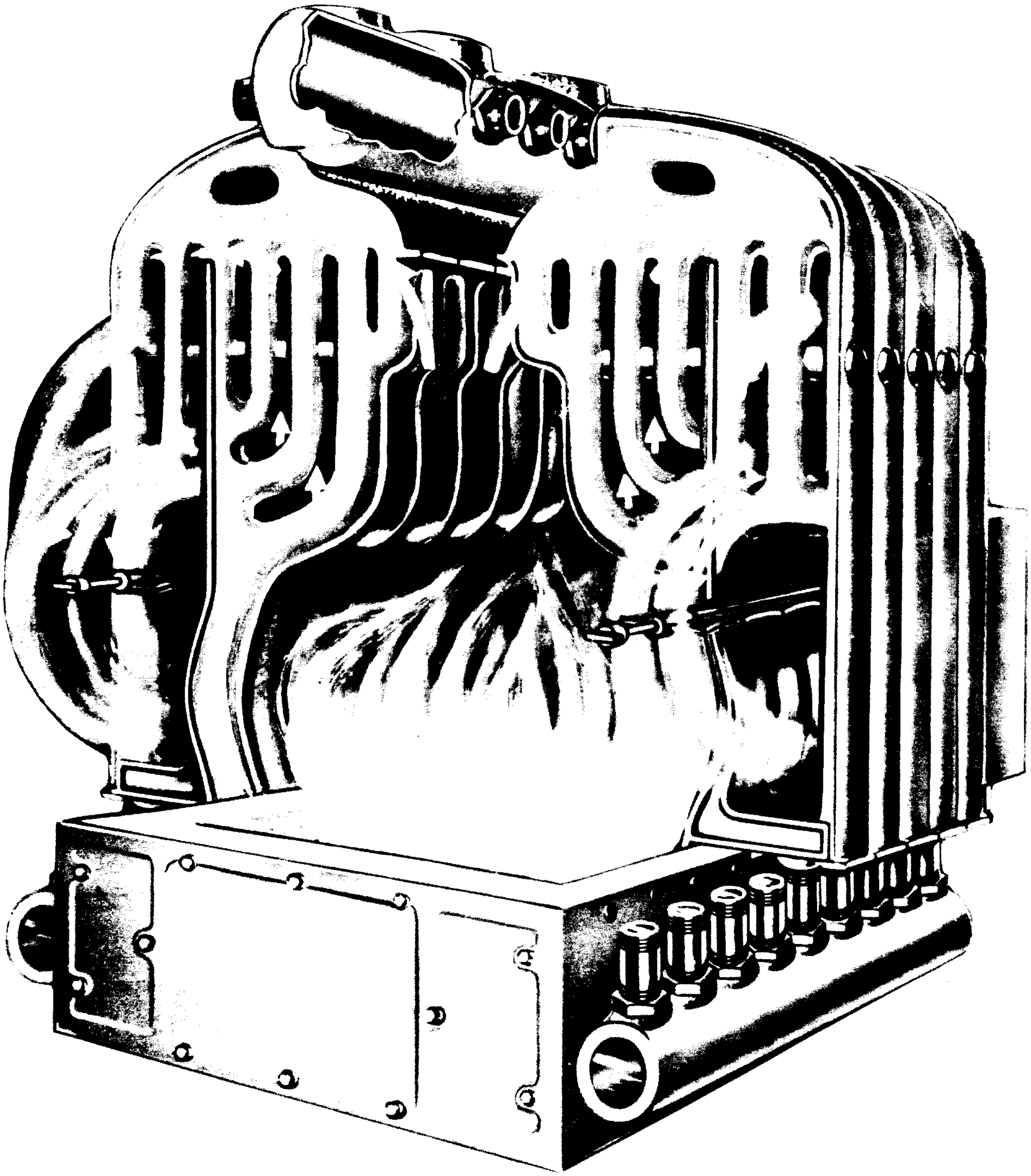


Fig. 4—External Header Boiler (H. B. Smith Co., Inc.)

is essentially surrounded by a refactory rather than water. The best example of an external furnace boiler is the ***horizontal return tubular (HRT) boiler*** (Fig. 5). These boilers are primarily designed for use as high-pressure boilers and are used for industrial process steam applications, although many are used for heating large buildings.

INTERNAL FURNACE BOILERS

4.04 Internal furnace boilers may have the furnace in the form of a straight flue completely surrounded by water as in the Scotch type, or may have the furnace substantially surrounded as in a firebox boiler where the water cooled surface is brought down to grate level on each side but is omitted on the bottom. See Fig. 6 and 7.

4.05 ***The portable firebox boiler,*** also called a compact or a smokeless boiler, is very popular for commerical and industrial installations and is one of the types commonly used in telephone buildings. It is a water leg boiler with two lengths of tube nests providing three passes for gas flow. It can be furnished for use with either natural gas, oil, or coal. This type boiler is available for field assembly, or it can be purchased as a package, with burner, controls and fittings installed at the factory.

4.06 ***The Scotch boilers*** used in modern heating systems are similar to those originally designed for shipboard installation and are sometimes called Scotch Marine Boilers. This boiler is available both for field assembly or as a package assembly and in some cases test fired and adjusted for maximum efficiency at the factory. This type boiler has a relatively low water capacity and, therefore, can be brought up to operating pressure quickly. It is economical in first cost, simple to install, and requires little headroom.

4.07 Scotch boilers are manufactured in two designs, the wet-back (Fig. 8) and the dry-back (Fig. 9) plus a modification of the former known as a wet-top or partial wet-back. The gas flow patterns vary from two pass to four pass and while these boilers can be adapted to any fuel they are ideally suited for natural gas or oil. Fig. 10 illustrates these.

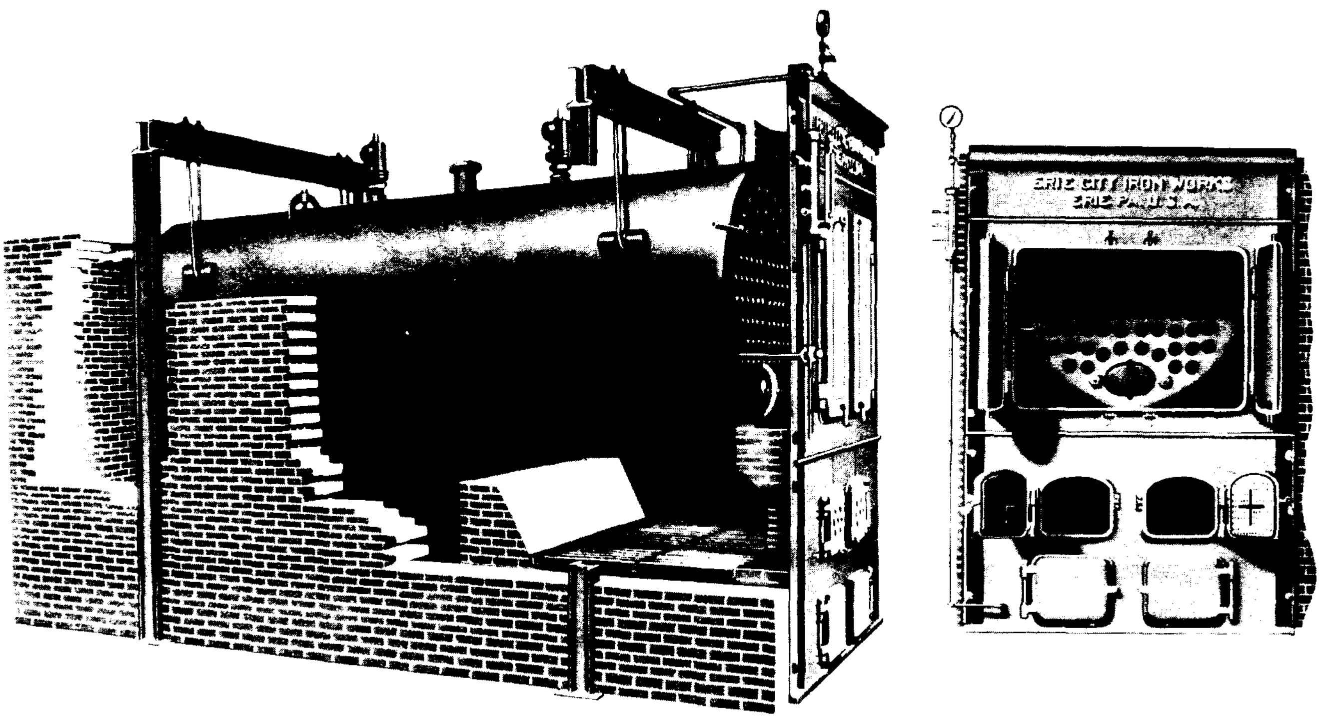


Fig. 5—Horizontal Return Tubular Boiler Showing Cut-Away Section and End View (Erie City Iron Works)

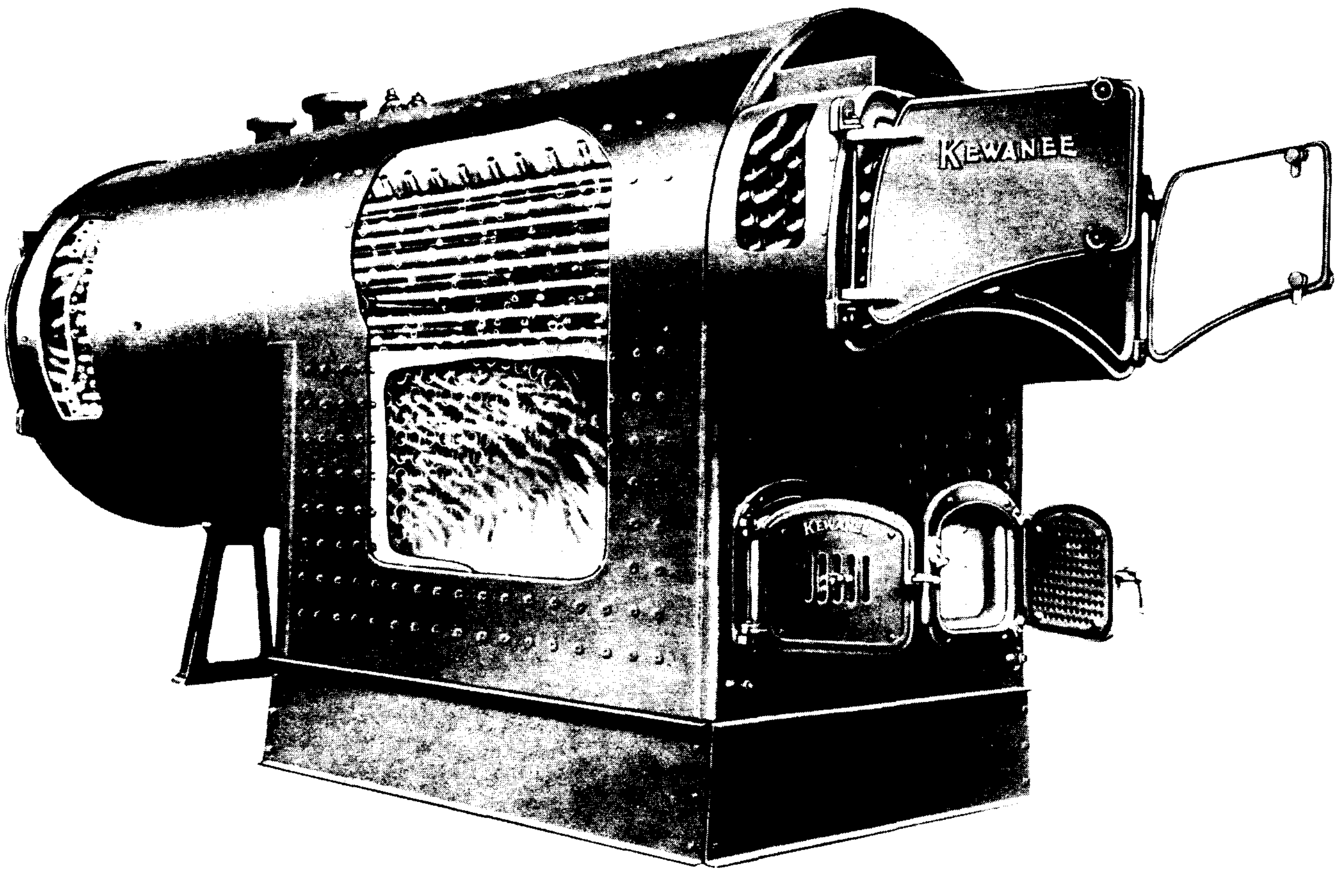


Fig. 6—Short Firebox Water-Leg Boiler (Industrial Division, American Radiator and Standard Sanitary Corp)

4.08 Most package Scotch boilers are of the dry-back or partial wet-back type and are arranged for multiple gas passes. This design allows for a minimum use of refractory lining material and provides a maximum capacity per square foot of heating surface.

5. FUEL TYPES

5.01 The principal fuels used to heat telephone buildings are oil and gas. The choice of fuel should be based on dependability, cleanliness, quality, availability, economy, maintenance, operating requirements, and control.

GAS

5.02 Natural gas is a popular fuel for heating telephone buildings. It burns clean without smoke, soot, or ash, and is very flexible from a combustion standpoint. High boiler efficiency can be achieved since gas is burned with relatively little excess air, and burner flexibility permits easy automatic control under varying load conditions. This fuel has a calorific value of approximately 1000 Btu/cubic foot. As this gas is normally distributed through underground piping, it requires no storage facilities.

OIL

5.03 Fuel oils are graded in accordance with specifications of the American Society of Testing Materials. Oils are classified by their viscosities. Other characteristics of fuel oils which determine their grade classification and suitability for given uses are the flash point, pour point, water and sediment content, carbon residue, ash and distillation characteristics. Fuel oils are prepared for combustion in most low-pressure boiler burners by atomization (spraying) and vaporization (heating). Atomization is further divided into three types,

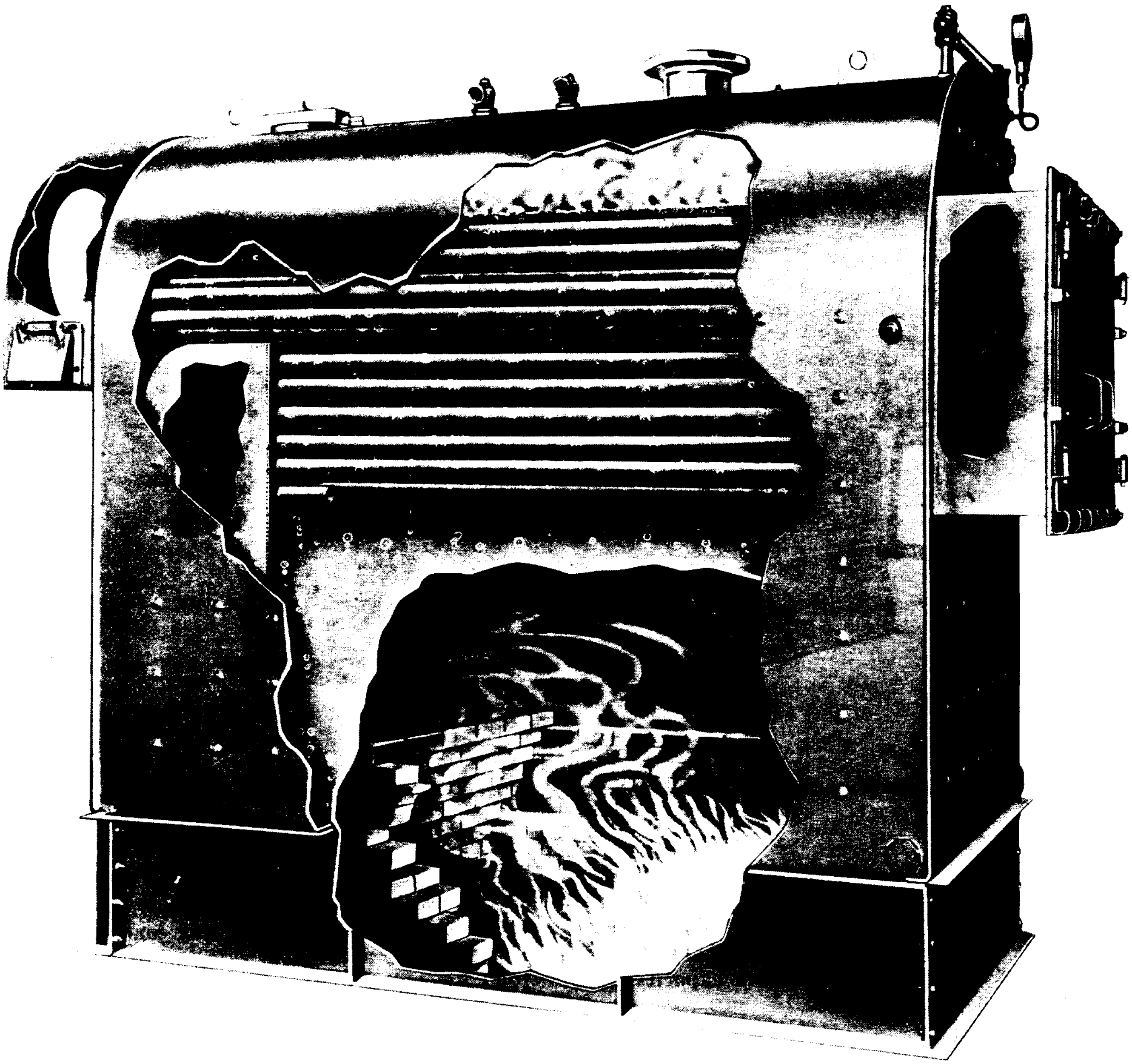


Fig. 7—Portable Firebox Boiler (Industrial Division American Radiator and Standard Sanitary Corp)

namely, high-pressure atomization, low-pressure atomization and centrifugal atomization. Fuel oil prices decrease as the grade number of the oil increases; eg, No. 6 is usually cheaper than No. 5.

Fuel Oil Grade Characteristics

5.04 *Grade No. 1*—A distillate oil intended for vaporizing pot type burners. The usual calorific value is 135,000 Btu/gal and the oil weighs 6.8 lbs/gal. This is not diesel fuel.

5.05 *Grade No. 2*—A distillate oil used for general purpose domestic heating and for use in high- and low-pressure atomizing burners not requiring No. 1. Before going to a heavier grade fuel oil careful consideration should be given to competitive prices, cost of fuel burning equipment,

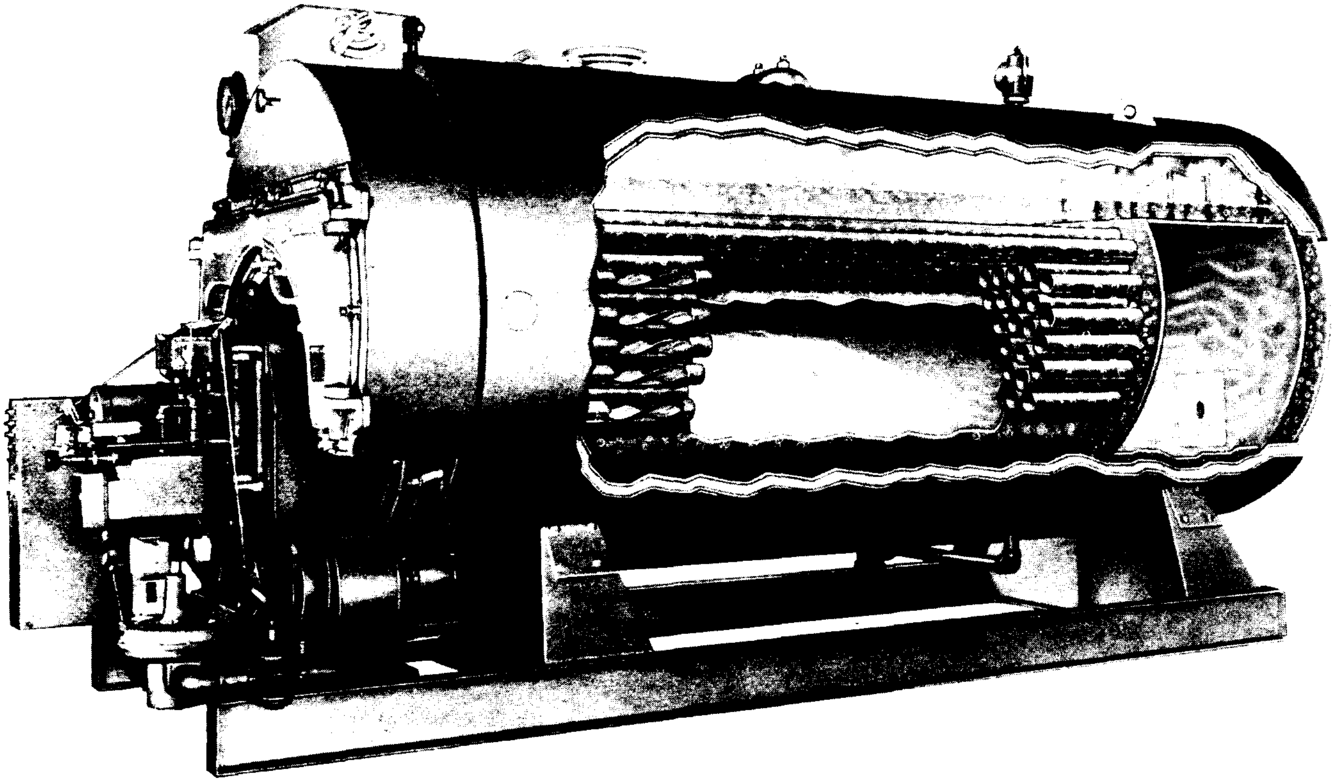


Fig. 8—Scotch Boiler, Wet-Back Type (Industrial Division, American Radiator and Standard Sanitary Corporation)

maintenance, and availability of qualified service. Burners using this fuel are available up to capacities of 20 gph without firing rate modulation. The usual caloric value is 138,000 Btu/gal and the oil weighs 7.1 lbs/gal.

5.06 *Grade No. 4*—An oil for burner installations that are not normally equipped with preheating facilities. This oil is generally used in burners employing centrifugal atomization (rotary cup burners) and modulating low-pressure gun type burners. Because the oil is no longer available in many locations as a straight run distillate, but is a mix of No. 2 and No. 6, it may be necessary in northern climates to provide tank heaters or small preheaters to ensure delivery of the fuel to the burner at a minimum temperature of 80°F. If the fuel is not blended properly under heat and pressure, the No. 2 and the No. 6 may separate in time. Be sure the fuel supplier has these blending facilities. Many dealers blend the two grades of oil in the tank truck while delivering to the location. This results in physical separation of the two grades, if they stand in the tank for any length of time. The usual calorific value is 147,000 Btu/gal and the oil weighs 7.7 lbs/gal.

5.07 *Grade No. 5*—A residual type oil for burner installations equipped with preheating facilities. The fuel is normally used in centrifugal atomizing burners. In the past this grade has been divided into hot No. 5 and cold No. 5. The hot grade had to be preheated and the cold could be burned as is from the tank, but because of the increased demand for distillate products the residual oils are lower in quality and must be preheated for good results. Sometimes Grade No. 5 is a mix of No. 2 and No. 6. The usual calorific value for this grade is 152,000 Btu/gal and the oil weighs 8.1 lbs/gal.

5.08 *Grade No. 6*—An oil for use in burners equipped with preheaters which permit the use of a high viscosity fuel. No. 6 fuel oil is commonly referred to as ***Bunker C.*** The usual calorific value for this grade is 153,000 Btu/gal and the oil weighs 8.2 lbs/gal.

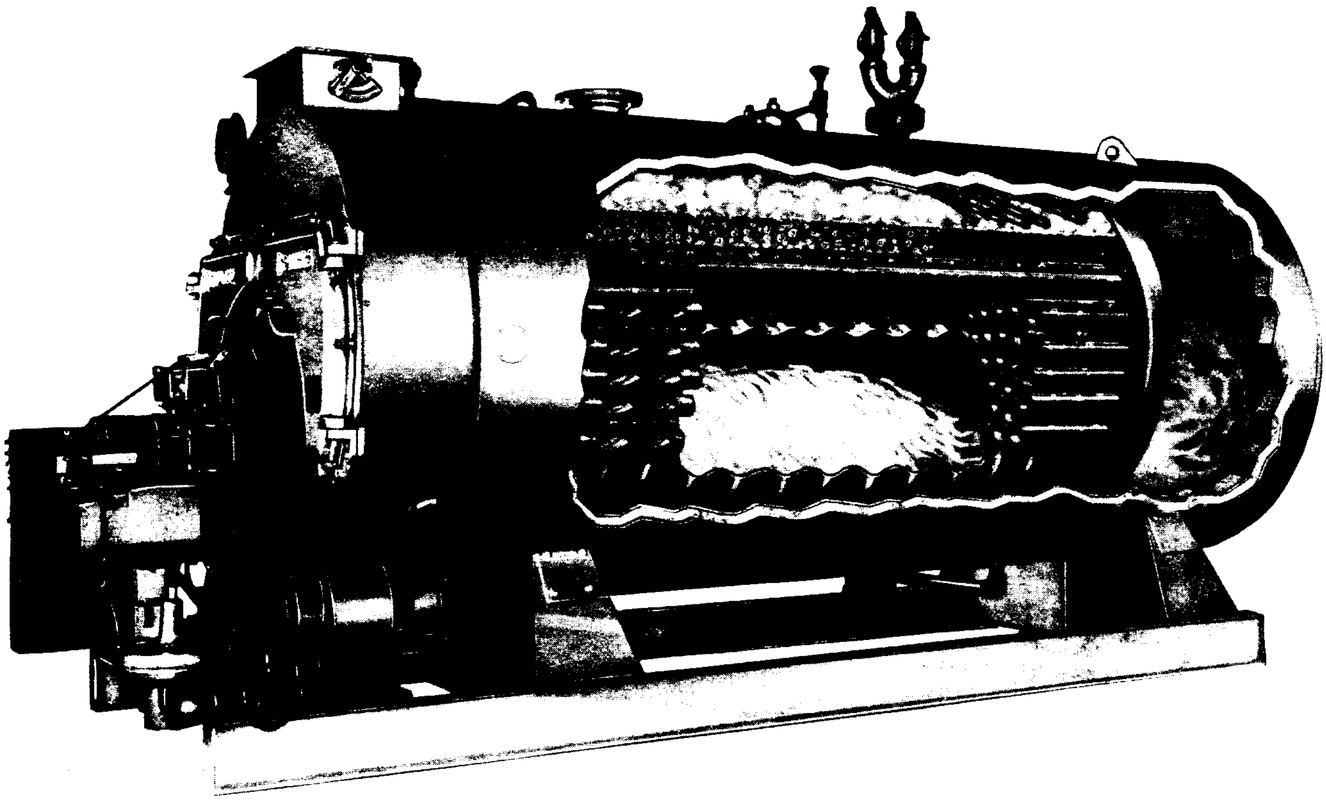


Fig. 9—Scotch Boiler Dry-Back Type (Industrial Division American Radiator and Standard Sanitary Corporation)

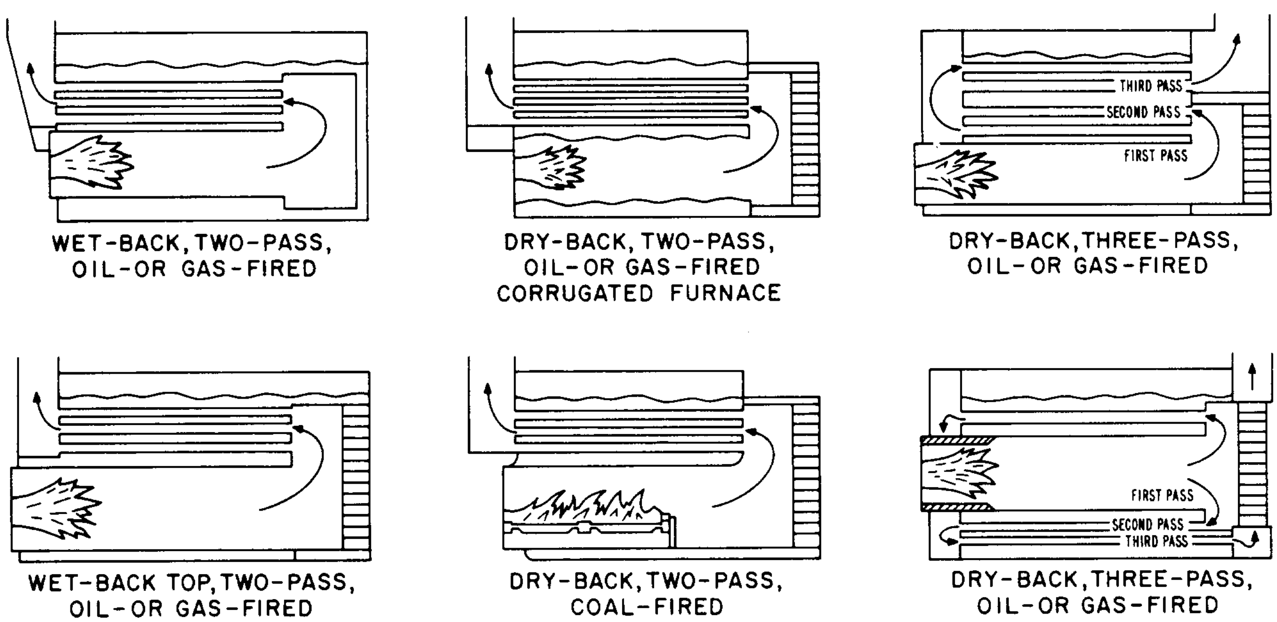


Fig. 10—Gas Flow in Scotch Boiler Types (From BOILERS by C. D. Shields. Copyright 1961. McGraw-Hill Book Co. Used by Permission.)

Preheating Requirements

5.09 The correct temperature range must be used for each grade of preheated oil. Underheating or overheating affects the terminal viscosity and actually interferes with the atomizing process. Underheated oil is too viscous for proper atomization, resulting in poor combustion, the generation of smoke and soot, and an excessively high oil consumption. Overheated oil, on the other hand, is too fluid for correct atomization and is subject to the same type of poor operating results as the underheated oil. To select the proper amount of preheating, the viscosity of the oil delivered should be obtained for each tank delivery. The viscosities for rotary cup atomizing burners are 150 to 450 SSU. No. 4 fuel oils, with a maximum viscosity of 125 SSU at 100°F, do not require preheating except where the oil is stored underground in northern locations. Cold No. 5 normally has a range of 150 to 200 SSU 100°F. Hot No. 5 normally has a range of 200 to 800 SSU 100.F. No. 6 (Bunker C) has a range of 900 to 1000 SSU 100°F. If the viscosity is known (obtain from oil dealer), then the correct temperature range can be selected from Fig. 11. The correct temperature should be obtained by raising the temperature of the oil in gradual steps through the table range until the most efficient combustion is obtained.

6. AUTOMATIC OIL BURNING EQUIPMENT

6.01 An oil burner mechanically mixes fuel oil and air and burns it under controlled conditions. Two methods, atomization and vaporization, are employed to prepare the fuel oil for combustion. Air for combustion is supplied by a blower incorporated in the burner or by draft produced by the chimney. Ignition is accomplished by an electric spark, electric resistance wire, gas pilot flame, or oil pilot flame. Burner operation may be intermittent or continuous with high-low or modulating flame.

6.02 ***Pressure Atomizing (Gun Type) Burners:*** Gun type burners are designed to burn No. 1 or No. 2 fuel oil. They may be divided into two classes: high-pressure and low-pressure atomization.

(1) The high-pressure atomizing type (Fig. 12) is characterized by an air tube, usually horizontal, with an oil supply centrally located in the tube and arranged so that a spray of atomized oil is introduced at about 100 psi and mixed in the combustion chamber with the air stream emerging from the air tube. The oil rate can be changed by replacing the nozzle with one of different rating. Nozzle size should be based on the firing rate. Once the rate is determined it should not be necessary to change the nozzle size. Small oil rate changes can be made by adjusting the oil pump pressure. Effective atomization is between 75 psi and 140 psi. Nozzles are stamped with ratings, angle of delivery and shape of flame, ie, ***1.50 gph 45.H.*** For capacities of over 3 gph, dual nozzles are normally used. The shape of the flame may be hollow (funnel shaped), semihollow, and solid. It is most important that the flame shape correspond to the shape of the furnace for good combustion. The flame must not impinge on the brickwork. The oil pump can function both as a pressure pump for atomization and as a suction pump to pump oil from the tank when the tank is below the burner. A blower is used to provide air for combustion. A damper (shutter) or other adjustable means at the burner and a draft regulator provide the proper air supply. Ignition is established by a high voltage electric spark that may operate continuously while the burner is running, or just at the beginning of the running period. The burner operates on the intermittent on-off principle with a luminous flame. The combustion process is completed in a furnace constructed of refractory material. The furnace should be sized and shaped for the quantity of fuel oil to be burned. The lining material should be of a type that glows readily, allowing the reflected heat from the refractory to stabilize the flame. In addition to this flame stabilization, the effective performance of pressure atomizing burners requires that the fuel be completely atomized and that combustion take place while the fuel is in suspension. This process requires that the air supplied for the combustion process be carefully adjusted for maximum effectiveness.

(2) The low-pressure atomizing burner differs from the high-pressure type mainly by having means for supplying a mixture of oil and primary air to the burner nozzle. The air meeting the mixture in the furnace is secondary air. The air pressure before mixing and the pressure of the air-oil mixture vary with different makes of burners, but are in the low range of 1 to 15 psig for air and 2 to 7 psig for the mixture.

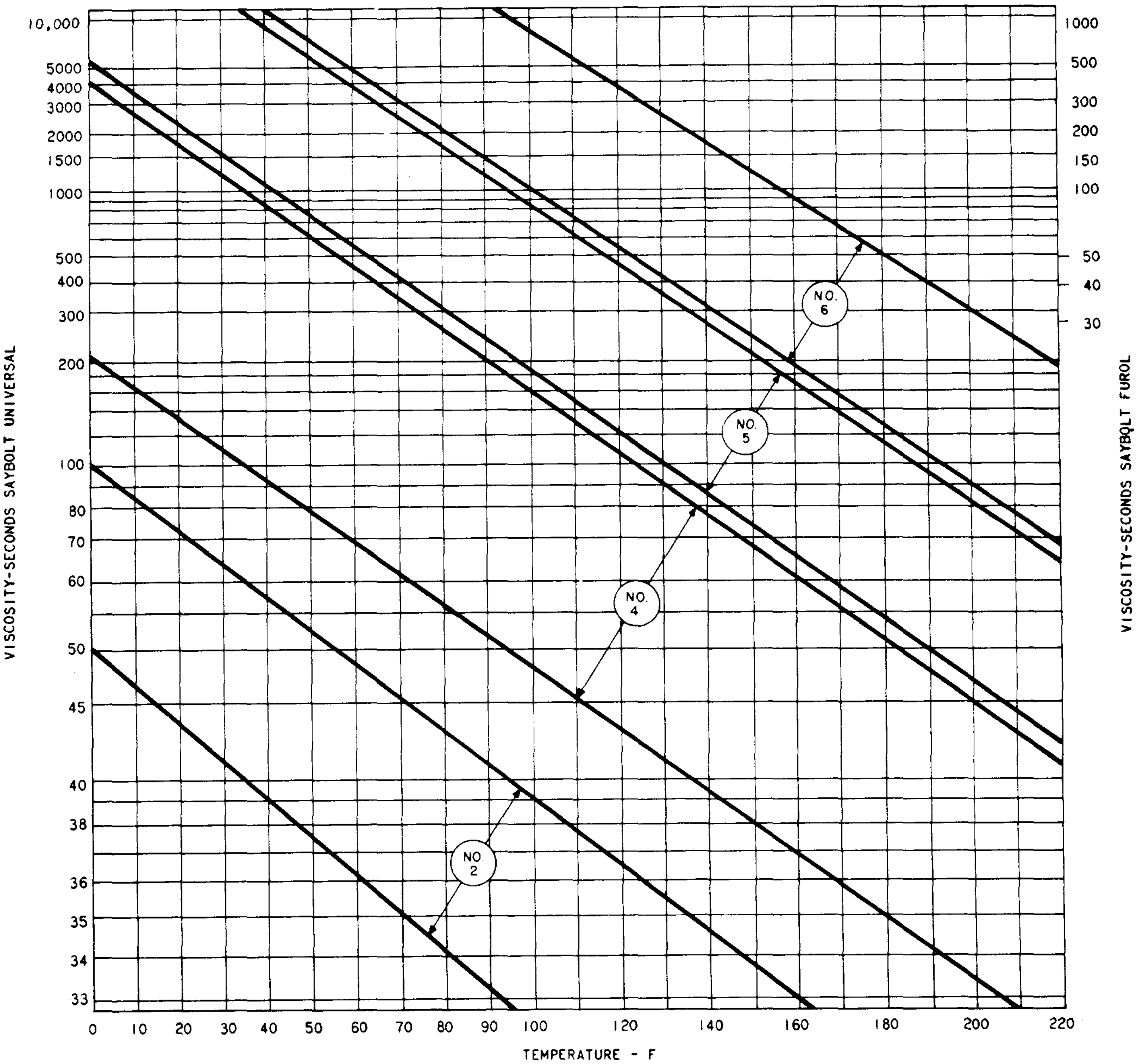


Fig. 11—Temperature-Viscosity Table (Reprinted with permission ASHRAE Guide and Data Book, 1963)

The nozzles, if properly maintained, will usually last for the life of the unit. Capacity of the burners is varied by making pump stroke or orifice changes on the oil pumps. These units do not need an external cartridge type filter on the oil supply lines because they have built-in screen strainers in the oil pump.

6.03 ***Horizontal Rotary Cup Burner:*** The horizontal rotary burner (Fig. 13) utilizes the principle of mechanical centrifugal atomization. The oil is prepared for combustion by centrifugal force, spinning it off a cup rotating at high speed, usually 3450 rpm. This type has a range running from 5 to 350 gph and can be used with all grades of fuel oil from No. 2 to No. 6. Heavy oils are preheated before they reach the cup. Another desirable characteristic of these burners is that of modulated firing. The capacity and flame size are controlled automatically by means of a modulating

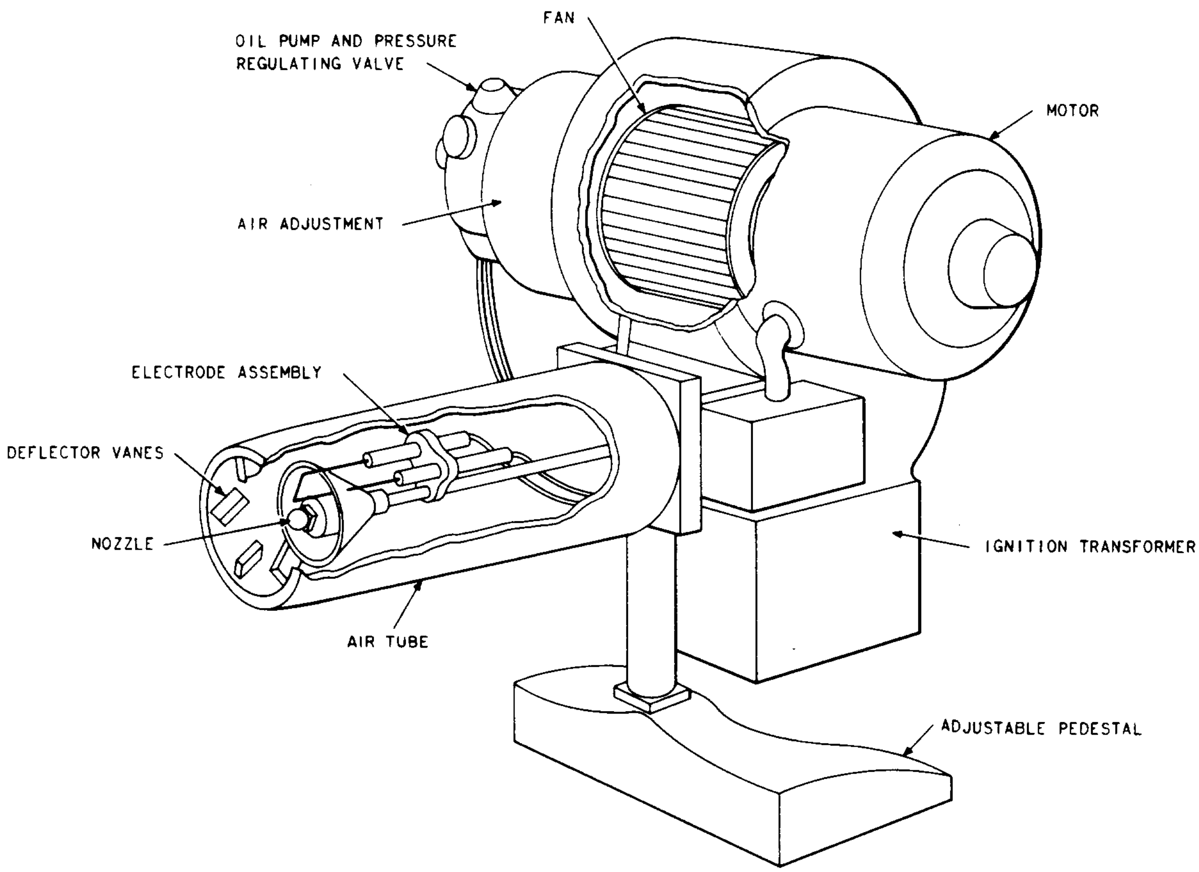
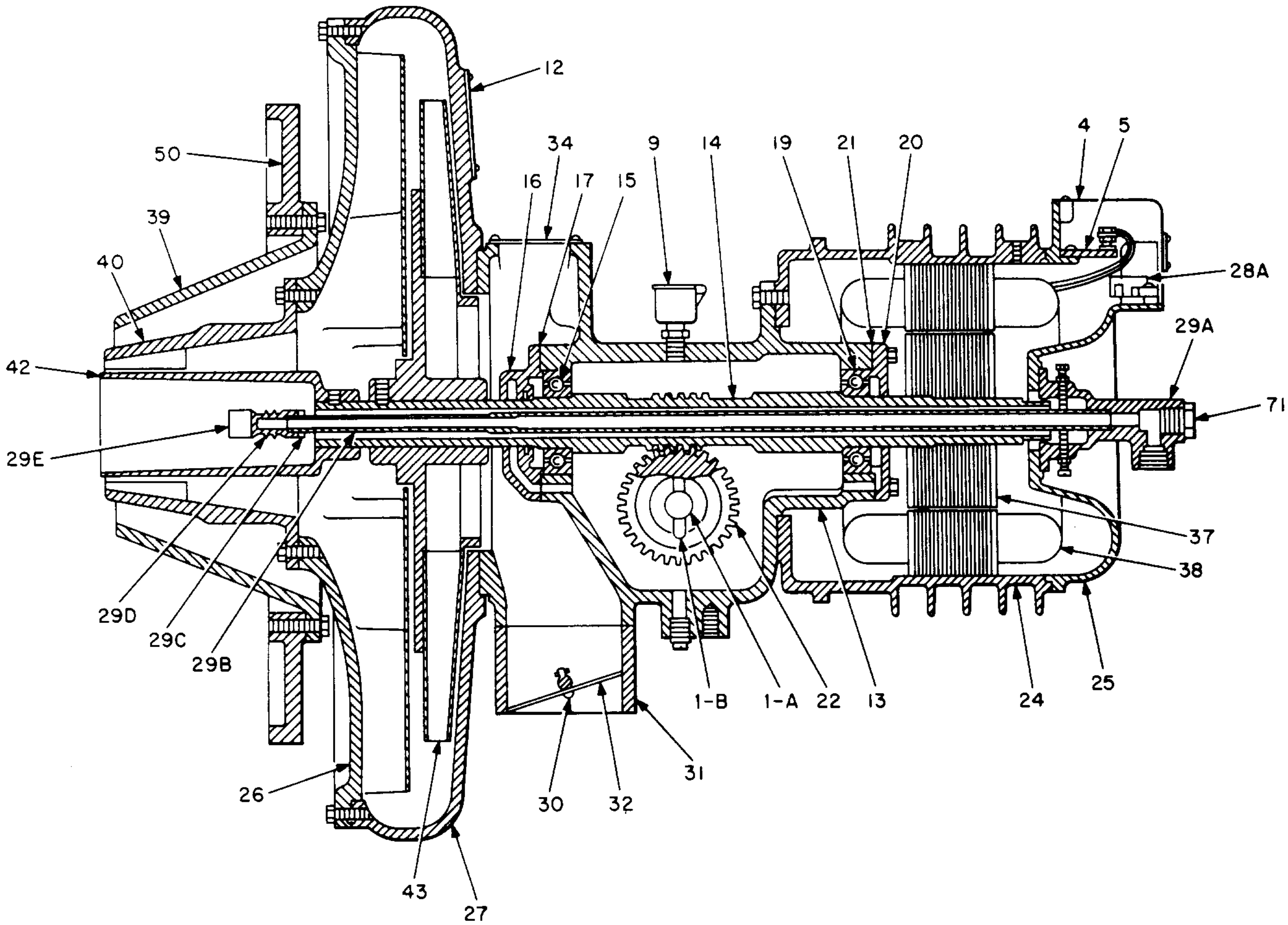


Fig. 12—High Pressure Atomizing Burner (Reprinted with permission ASHRAE Guide and Data Book, 1963)

motor controlled by steam pressure. The oil-air mixture is kept in the exact ratio necessary for good combustion. This modulation provides a means of always matching the burner capacity to the load, thus enabling the steam pressure to be kept reasonably constant. The range of the operating pressure control should bracket the desired modulating pressure range. Under this condition the burner will be on high fire at the minimum steam pressure necessary to heat the building. When the steam pressure increases over this point the burner modulates toward low fire. Normally the low fire is about 30 percent of the burner capacity at high fire. This low point of modulation is frequently called turndown.

6.04 ***Vertical Rotary Burner:*** These are the smaller rotary burners, and are used with No. 1 or No. 2 grade fuel oil. They are generally in the range of 1 to 7 gph. Oil is centrifugally thrown and mixed with air to a peripheral ring of stainless steel or refractory material. A refractory hearth is used to prevent excessive heat loss below the burner and to prevent air leakage. The fuel is ignited by gas pilot, electric spark, or hot wire. Primary air for combustion is supplied by the fan effect of the central spinner element while secondary air is supplied by natural draft. Oil flow rate and air quantity can be adjusted to suit requirements. Oil is fed by gravity to these burners and the flow is regulated by a constant leveling valve. It utilizes a float control to maintain a constant rate of oil flow. Positive shut off of the oil upon stopping is achieved by solenoid valves.

6.05 ***Flameviewing Devices:*** All heating plants are equipped with a viewing port for observing the flame. On small units these may be a hole with a metal cover in the vicinity of the burner or in large units the boiler shell may be equipped with a viewing port of heat and ultra-voilet resistant glass. It is important that the heating plant attendant be familiar with the characteristics of the flame for the particular type of burner and



1A - WORM GEAR SHAFT
1B - WORM GEAR PIN
4 - TERMINAL BOX COVER
5 - TERMINAL BLOCK ASSEMBLY
9 - OIL CUP STRAIGHT
12 - NAMEPLATE
13 - GEAR HOUSING
14 - BURNER SHAFT AND WORM
15 - FRONT BEARING
16 - FRONT BEARING COVER
17 - FRONT BEARING COVER GASKET
19 - REAR BEARING
20 - REAR BEARING COVER
21 - REAR BEARING COVER GASKET
22 - WORM GEAR
24 - MOTOR JACKET
25 - MOTOR JACKET COVER
26 - FAN CASE COVER ASSEMBLY
27 - FAN CASE
28A - STARTING RELAY (SIZE 5 SINGLE PHASE ONLY)
29A - TAIL PIECE
29B - FUEL TUBE ASSEMBLY
29C - LOCKNUT
29D - TIP
29E - VIBRATION DAMPER
30 - BUTTERFLY SHAFT
31 - BUTTERFLY HOUSING
32 - PRIMARY AIR BUTTERFLY
34 - HOUSING TOP PLATE
37 - ROTOR
38 - STATOR
39 - NOZZLE PROTECTOR
40 - NOZZLE ASSEMBLY
42 - ATOMIZING CUP
43 - FAN ASSEMBLY
50 - MOUNTING PLATE
71 - TAILPIECE PLUG

Fig. 13—Cross Section of Direct Drive Rotary Burner (Ray Burner Co.)

use the port for observations to assure that proper conditions are being maintained.

7. AUTOMATIC GAS BURNING EQUIPMENT

7.01 Burners for firing heating boilers with natural gas fall into two general classes, atmospheric and power type. Because of the ease with which gas fuel can be controlled, its use has become widespread and gas burning equipment is available for all types of boilers.

ATMOSPHERIC GAS BURNERS

7.02 ***Atmospheric Gas Burners:*** The atmospheric burners are used primarily on domestic and commercial type boilers. While all atmospheric gas burners are similar in the sense that all are of the Bunsen or injection type, they do differ in type of port and flame pattern.

(a) ***Drilled-port burners*** (bed type burners) are similar to those found in domestic gas ranges and are most frequently used on cast-iron boilers. The drilled ports produce many small flames on each burner. Burners are used in multiple to gain the desired capacity.

(b) ***Slotted-port burners*** are similar in design and appearance to drilled-port burners but the gas and air mixture is fed through a slot that extends the length of the burner head. This produces a long ribbon flame at each burner. These burners are also used in multiple.

(c) ***Single-port burners*** feed all the gas-air mixture through a single port, producing one large flame per burner instead of the many small flames produced by the drilled-port burner, or the long ribbon flame of the slotted-port burner. Single-port burners may be of the ***inshot*** type (Fig. 14 and 15) in which one or more burners are mounted on the front of the furnace or firebox and shoot flame into the combustion area, or the ***upshot*** type where the burner or burners are mounted in the bottom of the firebox and shoot the flame up into the combustion area. Upshot burners usually employ a flame spreader of metal or ceramic material which directs the flame outward. Single-port burners are normally used with natural draft applications. They are also very frequently employed as conversion burners when boilers designed for coal or oil are converted to natural gas firing.

POWER GAS BURNERS

7.03 ***Power Gas Burners*** for natural gas fall into two general types: pressure and forced draft. The pressure type is used for smaller commercial applications, usually with natural draft or induced draft. Forced draft burners are used for the larger commercial installations and for industrial applications.

(a) ***Pressure gas burners*** supply a mixture of gas and air to the combustion zone under pressure. In some types, the primary air and gas mixture is introduced through a nozzle while the secondary air is fed through an air diffuser, usually a ring shaped opening concentric with the nozzle. In another type known as a ***premixing burner*** all, or nearly all, of the combustion air is mixed with the gas and delivered through the burner nozzle or through a flame diffuser. Controls are provided for both types to modulate and properly proportion the air and gas supply for a variable firing rate.

(b) ***Forced draft gas burners*** deliver primary and secondary air under pressure by means of a blower. Gas is usually supplied from a ring with multiple ports (Fig. 16) that discharge into

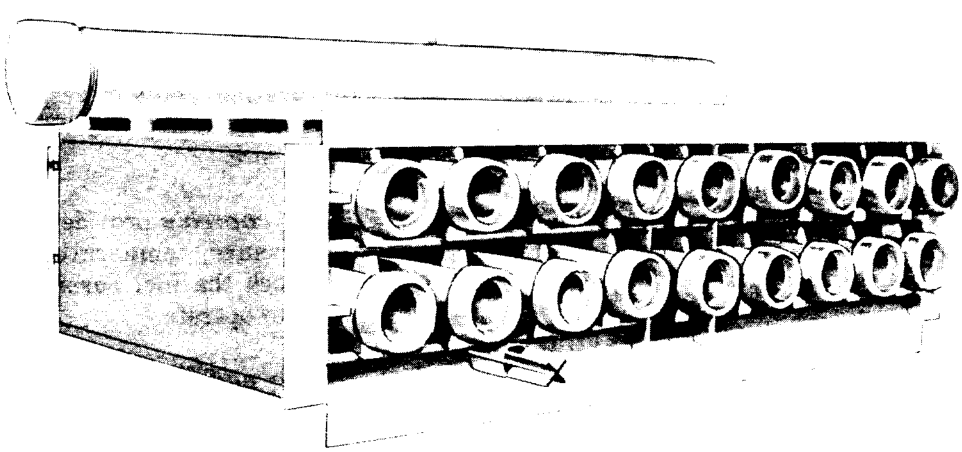


Fig. 14—Inshot Gas Burner—View From Combustion side (Ray Burner Co.)

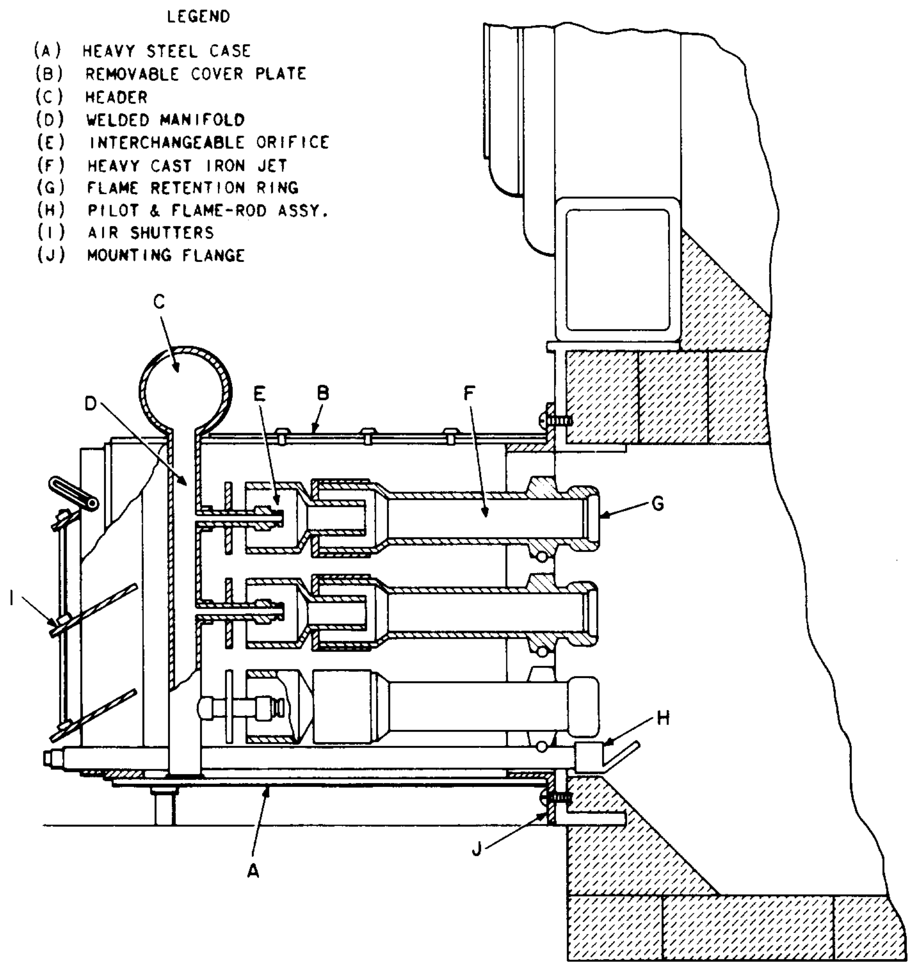


Fig. 15—Inshot Gas Burner—Cross Sectional View (Ray Burner Co.)

a forced air annulus at an angle to provide for aspiration of the gas, fast mixing, and flame retention. Secondary air is supplied under pressure through an outer air ring separated from the inlet rings by refractory material. These burners have modulating controls to provide a variable firing rate and can operate with either low- or high-pressure gas. The forced draft allows for efficient burning of fuel with reduced flue sizes, short stacks, or other conditions that will create adverse draft.

8. CONTROLS FOR LOW PRESSURE HEATING BOILERS

8.01 Controls are the brain center of the heating plant. There are four general classifications of controls:

(a) ***Combustion safeguard controls*** provide for the safe starting and operation of the burner. This classification of controls includes controls in the fuel piping.

(b) ***Operating controls*** initiate operation of the heating plant in response to a change in temperature, pressure, water level, time, or other influence.

(c) ***Limit controls*** provide for a definite limit in pressure, temperature, or water level beyond which the fuel burning apparatus is not permitted to operate.

(d) ***Safety controls*** operate automatically to relieve boiler overpressure that could be caused by a failure of any of the other controls.

8.02 Solenoids or drives of all electrical control devices must be powered with a nominal potential of 115 volts, and one side of the device

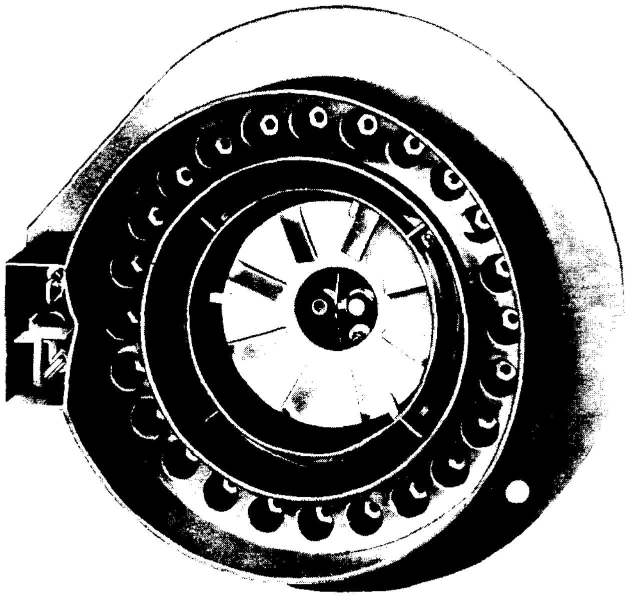


Fig. 16—Nozzle End of Forced Draft Combination Oil and Gas Burner (Industrial Division, American Radiator and Standard Sanitary Corporation)

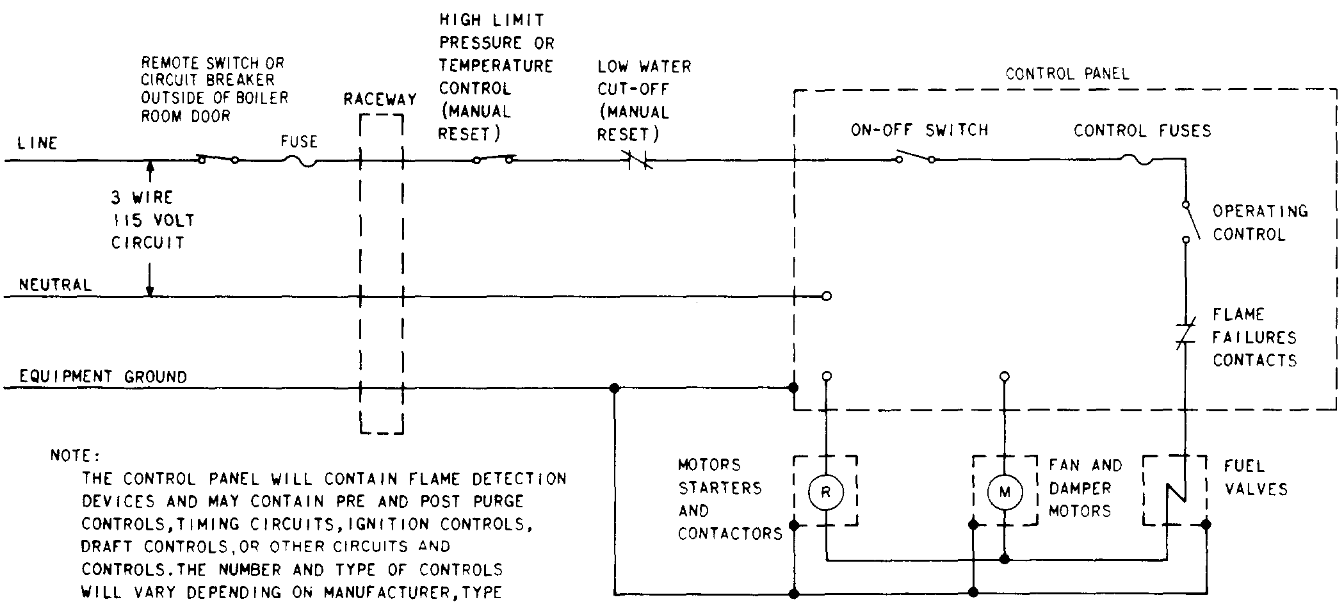
must be connected to the neutral or grounded side of the control circuit. A separate equipment ground conductor must be brought to the control panel frame with ground continuity assured to the fuel valve.

8.03 When an isolating transformer is used, it must be bonded to the control panel frame, and ground continuity to the fuel valve must be assured. The equipment ground to the control cabinet is not required when an isolating transformer is used. The control circuit requirements and high temperature or high pressure and low water limit control locations in the control circuit for a 3-wire 115 volt system and a 2-wire 115 volt system with an isolation transformer are illustrated in Fig. 17 and 18, respectively.

8.04 Electrical contacts of all limit and operating controls shall be in series with the line or "hot" side of the control circuit so as to de-energize the controlled device when the operating or limit control is actuated.

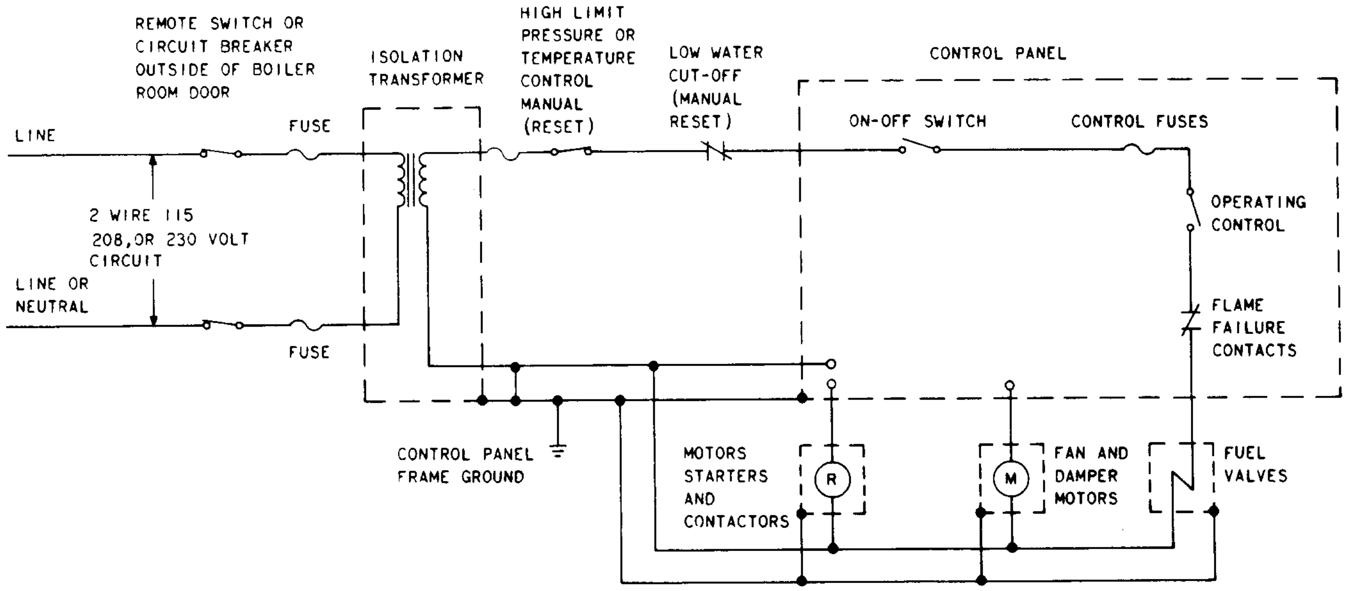
COMBUSTION SAFEGUARD CONTROLS—REQUIREMENTS

8.05 The number and type of combustion controls required on a particular heating plant depends on the capacity of the burner and the type of fuel burned. There are four classifications based on capacity and fuel type, each requiring controls that provide specific safeguards.



NOTE:
THE CONTROL PANEL WILL CONTAIN FLAME DETECTION DEVICES AND MAY CONTAIN PRE AND POST PURGE CONTROLS, TIMING CIRCUITS, IGNITION CONTROLS, DRAFT CONTROLS, OR OTHER CIRCUITS AND CONTROLS. THE NUMBER AND TYPE OF CONTROLS WILL VARY DEPENDING ON MANUFACTURER, TYPE OF FUEL, SIZE OF HEATING PLANT, AND DEGREE OF AUTOMATION.

Fig. 17—3 Wire 115 Volt Control Systems



NOTE:
THE CONTROL PANEL WILL CONTAIN FLAME DETECTION DEVICES AND MAY CONTAIN PRE- AND POST-PURGE CONTROLS, TIMING CIRCUITS, IGNITION CONTROLS, DRAFT CONTROLS, OR OTHER CIRCUITS OR CONTROLS. THE AMOUNT AND TYPE OF CONTROLS WILL VARY DEPENDING UPON MANUFACTURER, TYPE OF FUEL, SIZE OF HEATING PLANT AND DEGREE OF AUTOMATION.

Fig. 18—2 Wire 115 Volt, 208 Volt, or 230 Volt Control System

8.06 ***Combustion Controls for Burners Using Light Oil (#1 to #3) and Having Up To 20 gph Capacity*** shall:

1. Shut off the fuel supply if ignition does not take place.
2. Where low fire start is provided, prove the burner in that position before ignition can be attempted.
3. Shut off the fuel supply in the event of a flame failure.
4. Test for presence of air supply in burners over 10 gph capacity or where separate fans are installed.
5. Shut off the fuel supply if the ambient room temperature in the burner area exceeds limits determined by the control sensing unit.

8.07 ***Combustion Controls for Burners Using Light Oil or Heavy Oil (#4 to #6) and Having Over 20 gph Capacity*** shall:

1. Test for low fire start position of burner.
2. Provide for a safe start check of programmer circuitry.
3. Provide for pre-purge of combustion chamber.
4. Determine presence of pilot.

5. Shut down the burner if pilot is not verified.

6. Shut off fuel supply if main flame is not verified or if flame failure occurs during "burner on" cycle.

7. Provide for post-purge of combustion chamber.

8. Maintain oil temperatures between prescribed limits.

9. Shut off the fuel supply if the ambient room temperature in the burner area exceeds limits determined by the control sensing unit.

10. Shut down fuel valves in case of inadequate air flow.

8.08 ***Combustion Controls for Burners Using Gas and Having up to 200,000 Btu/hr Input*** shall:

1. Provide for continual supervision of pilot flame.

2. Shut off fuel supply in the event of pilot flame loss.

3. Regulate main gas line pressure and independently regulate pressure in pilot gas line.

8.09 ***Combustion Controls for Burners Using Gas and Having over 200,000 BTU/hr Input*** shall:

1. Regulate the gas pressure in the pilot gas line.

2. Supervise pilot so that loss of pilot completely shuts down the burner.

3. Regulate the gas pressure in the main burner gas line.

4. Shut off the fuel supply on low gas pressure.

5. Shut off the fuel supply on high gas pressure.

6. Provide a safe start check of the programmer and sensor before every cycle.

7. Provide low fire start when low fire start is required.

8. Provide for preignition purging.

9. Provide a timed trial for ignition of pilot and main flame.

10. Provide for post-purge of combustion chamber.

11. Shut off the fuel supply in the event of main flame failure.

COMBUSTION SAFEGUARD CONTROLS—ARRANGEMENTS

8.10 The arrangement and function of the required controls installed in the fuel piping for a heating plant depends on the capacity of the burner and the type of fuel burned.

8.11 ***Combustion Control Arrangement for Burners Using Light Oil and Having Up to 20 gph Capacity*** is shown in Fig. 19. The functions of the controls are as follows:

1. ***Stop Valve:*** A manual shutoff valve is provided immediately upstream of the fuel oil filter. A second valve, to be used in the event of fire, may be located where the oil suction line enters the building.

2. ***Temperature Actuated Shutoff Valve:*** This valve will shut down the system in the event the ambient air temperature exceeds its setting. It may be either self-contained and spring loaded, weighted with fusible link, or a string switch. The actuating device should be as close to burner as possible.

Caution: A shutoff valve should be installed where the oil suction line enters the building. A temperature actuated shutoff valve should be installed if a manual shutoff valve is not used.

3. ***Automatic Fuel Shutoff Valves:*** Two solenoid operated fuel shutoff valves are required. Both valves are actuated by the combustion, operating, and limit controls. Valves should have spring return or weighted level action to help prevent sticking. On high pressure atomizing burners one of the

fuel shutoff valves shall have the delayed opening feature to assure the burner motor is at operating speed before fuel is fed to the burner.

8.12 ***Combustion Control Arrangement for Burners Using Light Oil or Heavy Oil and Having Over 20 gph Capacity*** is shown in Fig. 20. The functions of the controls are as follows:

1. Control arrangement is the same as for up to 20 gph capacity installations except for the addition of an electric oil heater with high and low temperature cut-outs in the fuel oil line. The high temperature cut-out is manually reset. The low temperature cut-out is automatically reset.

2. Pilot piping arrangement is the same as for gas fuel installations.

3. For installations using preheated oil, the coils on solenoid valves shall have insulation with a class H rating.

8.13 ***Combustion Control Arrangement for Burners Using Gas and Having up to 200,000 Btu/hr Input*** shall be in accordance with Fig. 21. The functions of the controls are as follows:

(1) ***Stop Valve:*** A manual gas service shutoff valve furnished by the gas company is usually installed where the gas service enters the building. If the distance from this point to the boiler room is greater than 50 feet, a second manual shutoff valve is installed outside the boiler room door not more than 6 feet from the floor.

(2) ***Pilot Gas Cock—Gas Cock:*** Manual shutoff valves are installed in the pilot gas line and the main burner gas line. These valves should be shut-off cock designed for gas service and have an operating handle attached parallel to the gas flow in the open position.

(3) ***Pilot Burner:*** The pilot burner gas line is taken off the main gas service before the supply to the main burner. Some upshot natural gas burners may have more than one pilot installed to ensure a safe light-off. All such pilots must be supervised continually. The pilot line also has its own pressure regulator. If the gas pressure fluctuates, this regulator should be a minimum 1/2 inch I.P. size. The pilot may be interrupted, intermittent, or constant. If a constant pilot is used, it shall be equipped with

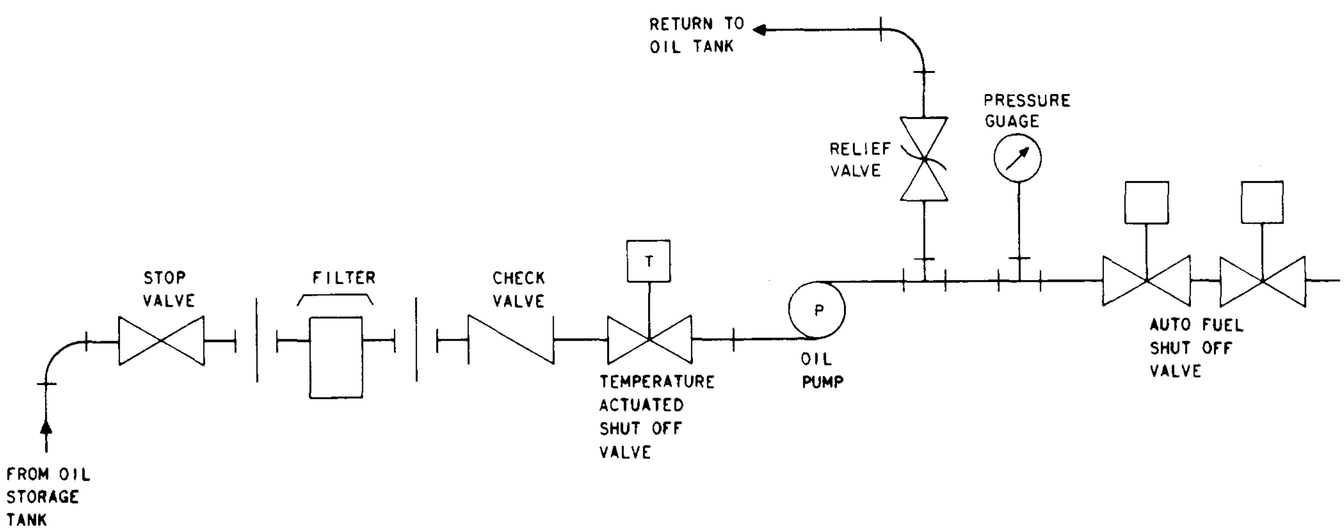


Fig. 19—Fuel Control for Light Oil Heating Plant Installations Up to 20 GPH Capacity, Electric Arc Ignition of Burner Flame

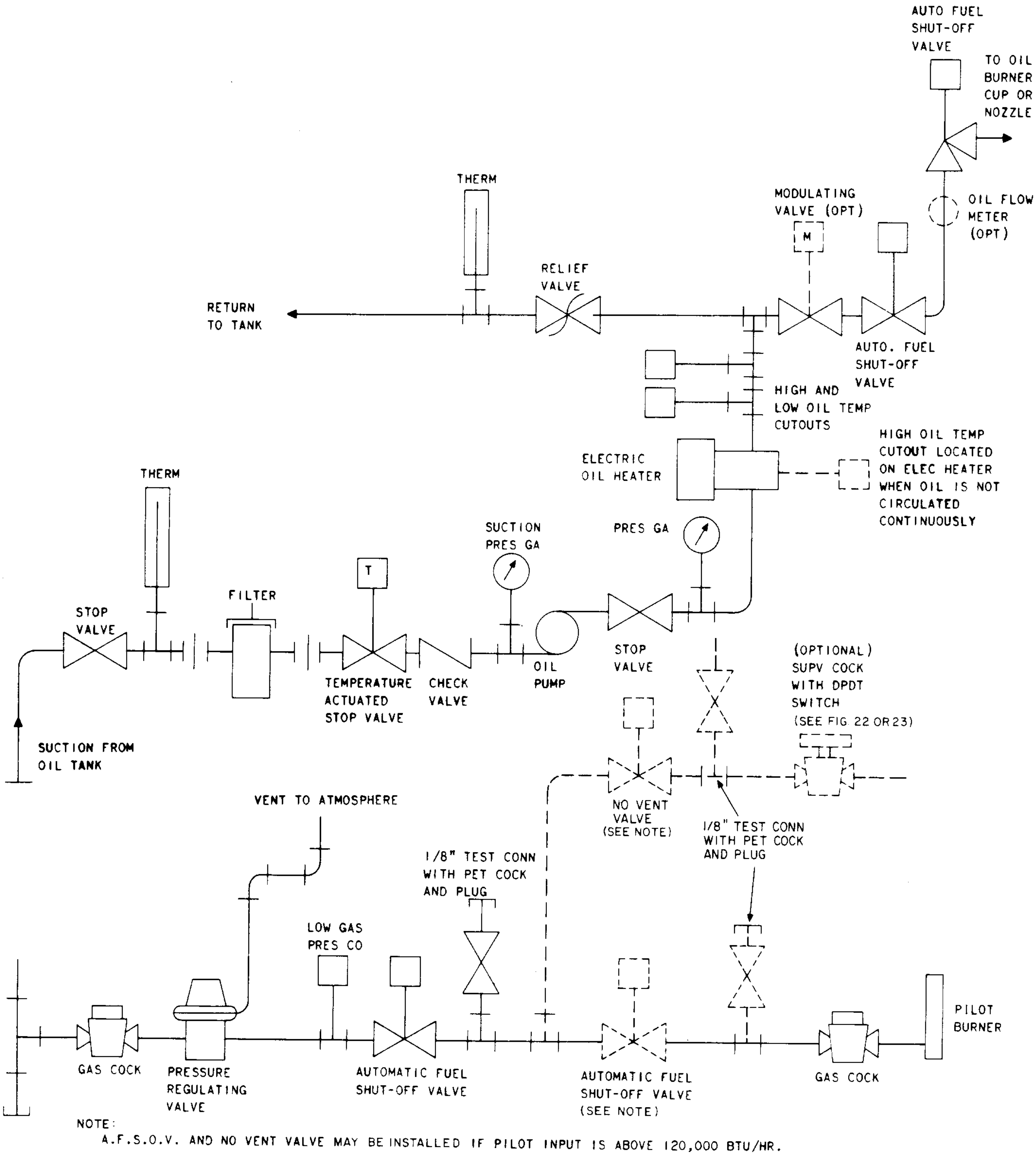
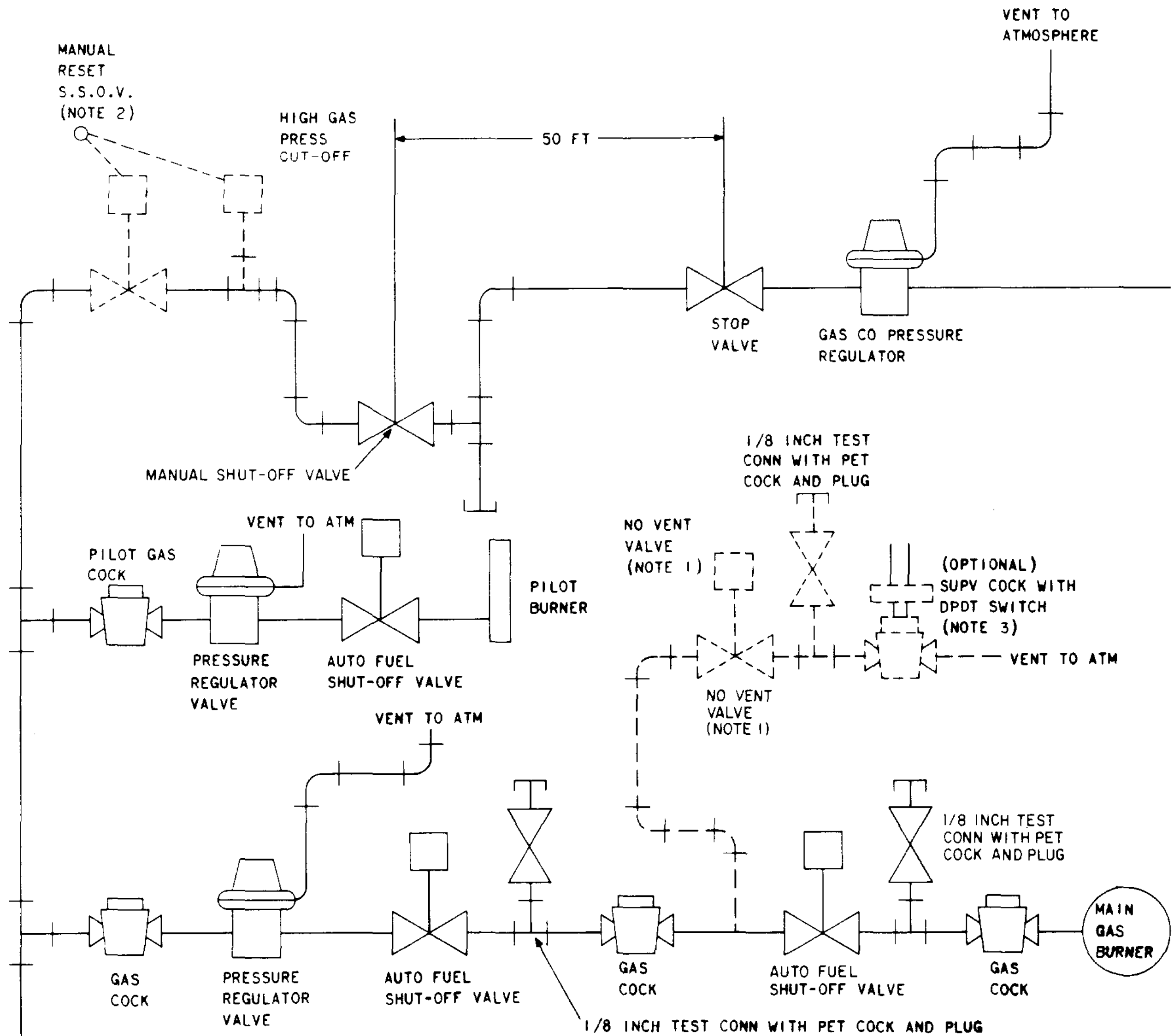


Fig. 20—Fuel Control for Heavy Oil and Light Oil Installations Over 20 GPH Capacity, Electric Arc Ignition of Gas Pilot



NOTES:
1. NORMALLY OPEN VENT VALVE MAY BE INSTALLED WHEN GAS INPUT TO BURNER EXCEEDS 120,000 BTU/HR.
2. THIS VALVE IS TO BE OPERATED BY THE ADJACENT HIGH GAS PRESSURE CUT OUT INSTALLED FOR OPTIONAL VENTING OF DIAPHRAGM APPLIANCES TO STANDING PILOT.
3. DPDT SWITCH INSTALLED TO ENERGIZE AUTOMATIC FUEL SHUT-OFF VALVES AND VENT VALVE WITHOUT OPERATING THE BURNER.

Fig. 21—Fuel Control for Gas Heating Plant Installations with Up to 200,000 BTU/hr Input

an automatic 100 percent shut off valve that closes on loss of pilot flame.

(4) ***Pressure Regulator Valve:*** The main gas line is provided with a gas appliance pressure regulator separate from that normally provided by the gas company. Pressure regulators are of the dead weight or pressure balance types. Under no circumstances should a weight and lever type of regulator be used. Regulators should be able to maintain the required gas pressure at the inlet of the burner, plus or minus 10 percent from maximum to minimum firing rates.

(a) The space above the diaphragm in the regulator should be vented to the outside of the building at least 10 feet above grade, not directly below a window opening, and at least 5 feet laterally from any building opening. Vents from pressure regulators should not be connected in a common line with vents from relief valves or gas operated diaphragm valves.

(b) Some installations that use constant pilots may vent the control diaphragm chamber into the pilot flame. When this is done, the vent between the two automatic fuel shutoff valves is eliminated and a manual reset safety shutoff valve is installed in the gas main. This valve should be rated to close against the maximum gas pressure available. A manual reset high pressure switch, installed upstream from this valve and wired on a separate control circuit, activates the shutoff valve when the main gas pressure exceeds the normal by 25 percent.

(5) ***Automatic Fuel Shut off Valves:*** Two fuel shutoff valves are provided to positively stop the flow of gas to the burner upon direction from either the combustion, operating, or limit controls. These valves should have the capacity of closing against 5 psi or the maximum gas pressure available. Both these valves may be of the following types:

(a) Motorized valve with spring return to the closed position.

(b) Line or low voltage solenoid valve.

(c) Any automatic valve which has the operating characteristics of a motorized valve, does ***not*** use a diaphragm in its construction, and has a spring return to its closed position. Some installations may be equipped with one of the fuel shutoff valves as listed above and the other a solenoid operated diaphragm valve, a gas operated diaphragm valve, or a heat actuated diaphragm valve. If a diaphragm type of valve is used and should become defective, replace it with a valve (a., b., or c.) that does not use a diaphragm. Care should be taken in venting gas operated diaphragm valves. They ***must be*** vented to the atmosphere and not to a continuous pilot.

(6) ***N.O. Vent Valve:*** Installations exceeding 120,000 Btu/hr input may utilize a gas leak detection vent line. This consists of a vent line equipped with a normally open solenoid valve (N.O. Vent Valve) connected to the main gas line between the two shutoff valves. The valve is open when the gas shutoff valves are closed and is energized to the closed position when the gas shutoff valves are open. An optional feature is a supervisory cock with a double pole, double throw switch to facilitate testing (see Sections 770-210-301 and 770-210-302 for test procedures).

8.14 ***Combustion Control Arrangement for Burners Using Gas and Having Over 200,000 Btu/hr Input*** is shown in Fig. 22. The functions of the controls are as follows:

(1) ***Stop Valve:*** Same as for gas burners up to 200,000 Btu/hr input. See 8.13(1)

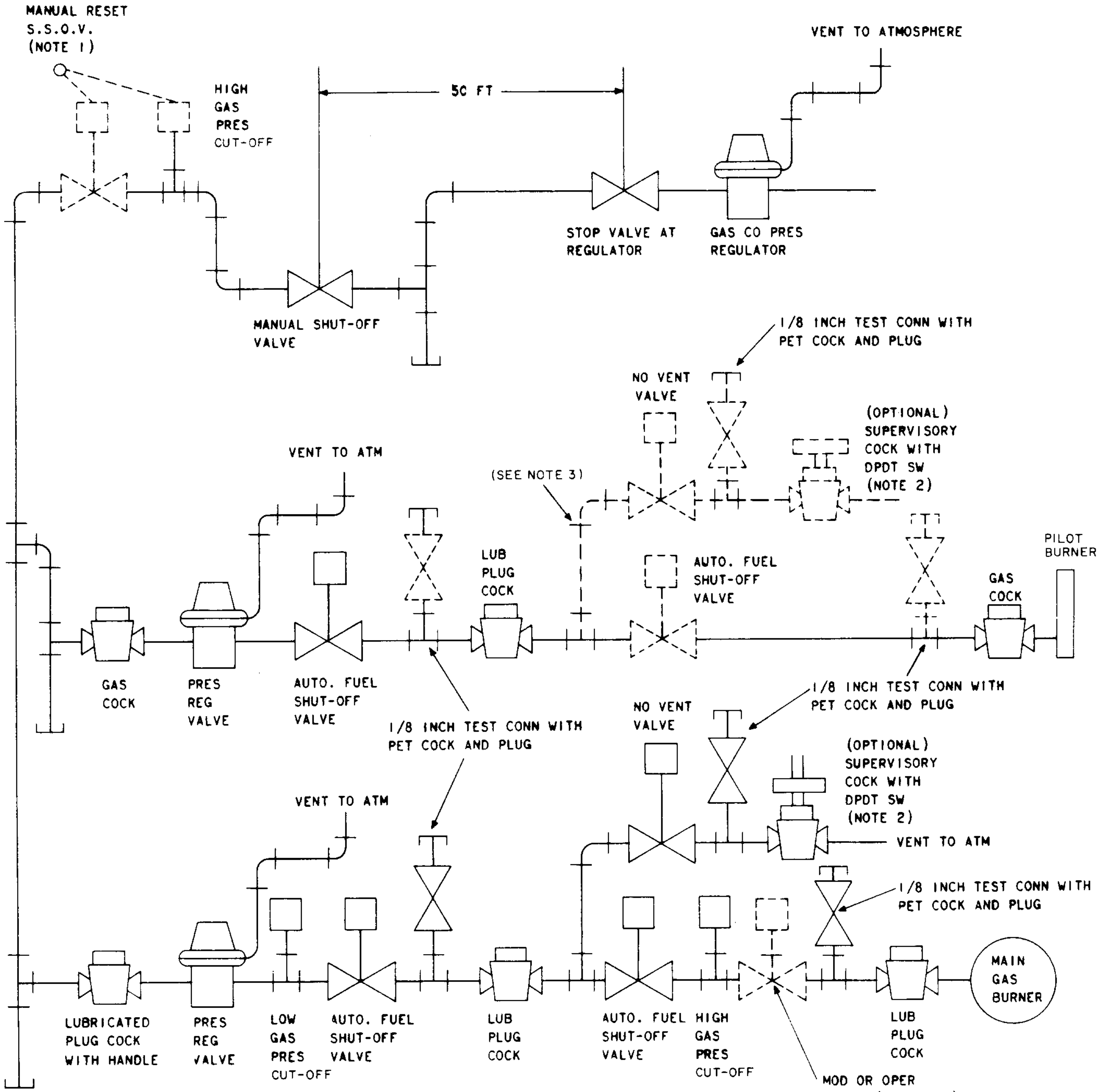
(2) ***Gas Cock:*** Same as for gas burners up to 200,000 Btu/hr input. See 8.13(2)

(3) ***Pilot Burner:*** The pilot burner gas line is taken off the main gas service before the supply to the main burner. The pilot line is provided with its own manual shutoff cock, pressure regulating valve, and automatic fuel shutoff valve. If the gas pressure fluctuates, this regulator should be a minimum of 1/2 inch I.P. size. Large atmospheric, upshot burners usually contain more than one pilot. One pilot is designated as a Safe Light Pilot, which is a spark ignited, constant or intermittent pilot, electronically supervised with a 100 percent shut off of the pilot gas line. Other pilots may be supervised by thermocouple detectors, but all must be lit in order to supply gas to the safe light pilot. Pilots may be constant, intermittent, or interrupted. Pilots over 120,000 Btu/hr rating may have two shut off valves and a vent as described in 8.13(6).

(4) ***Pressure Regulator Valve:*** Same as for gas burners up to 200,000 Btu/hr input. See 8.13(4).

(5) ***Low Gas Pressure Cut Off—High Gas Pressure Cut Off:*** High and low gas pressure switches are provided in the main gas line. These switches should be of the manual reset type and wired to shut down both fuel valves.

(6) ***Automatic Fuel Shutoff Valves:*** Two fuel shutoff valves are provided to positively stop



NOTES:

1. THIS VALVE IS TO BE OPERATED BY THE ADJACENT HIGH GAS PRESSURE CUT OUT INSTALLED FOR OPTIONAL VENTING OF DIAPHRAGM APPLLIANCES TO STANDING PILOT.
2. DPDT SWITCH INSTALLED TO ENERGIZE AUTOMATIC FUEL SHUT-OFF VALVES AND VENT VALVE WITHOUT OPERATING THE BURNER.
3. VENT MAY BE INSTALLED IF PILOT EXCEEDS 120,000 BTU/HR.

Fig. 22—Fuel Control for Gas Heating Plant Installations with Over 200,000 BTU/hr Input

the flow of gas to the burner upon direction from either the combustion or limit controls. The valves should have the capacity of closing against a gas pressure of at least 5 psi and be either a motorized valve with a spring return to the closed position or any operating valve which has the operating characteristics of a motorized valve, does not use a diaphragm in its construction, and has a spring return to its closed position. Closing time of these valves depends on the Btu/hr input to the burner. From 200,000 Btu/hr to 5,000,000 Btu/hr the closing time is 2 seconds. Over 5,000,000 Btu/hr the closing time is 1 second. Some installations may have one motorized type of valve and a solenoid operated diaphragm valve. If a diaphragm valve is used, it should be vented to the atmosphere. When repairs or replacements are required on diaphragm type valves these valves should be replaced with a motorized type.

(7) ***N.O. Vent Valve:*** Some gas installations may utilize a gas leak detection vent line. This consists of a vent line equipped with a normally open solenoid valve (N.O. Vent Valve) connected to the main gas line between the two shutoff valves. The valve is open when the gas shutoff valves are closed and is energized to the closed position when the gas shutoff valves are open. An optional feature is a supervisory cock with a double pole, double throw switch to facilitate testing (see Sections 770-210-301 and 770-210-302 for test procedures).

COMBUSTION CONTROLS—PROGRAMMING, SENSING, DRAFT CONTROL, AND OIL PREHEATING

Programmers And Flame Sensors

8.15 ***The functions of the programmer and the flame sensor*** are to assure safe start-up and operation of the burner. The type of programmer used in a heating plant will generally depend on the capacity of the plant, and accordingly, the complexity of the programmer will vary from a thermocouple-automatic fuel shutoff valve unit to an appliance with a self-checking electronic circuit that automatically sequences all phases of burner operation.

8.16 ***The type of flame sensor*** used will depend on the programmer arrangement. The flame sensor will ascertain the presence of a standing or an intermittent pilot, or when an interrupted pilot is used, ascertain that the main burner has been ignited. The three most common types of flame sensors are a thermocouple, a flame rod, and a scanning type detector.

8.17 ***A thermocouple sensor*** in the presence of a flame generates a current to actuate an electrical-mechanical circuit that will assure safe operation of the burner. Thermocouples are used on gas burners and require a standing pilot.

8.18 ***A flame rod sensor*** is an electrical conductor that, when in contact with the flame, generates a direct current signal. The dc signal, through an electronic circuit, indicates the presence of a flame. Flame rod sensors are used on gas burners and on gas pilots on oil burners. The flame rod detection system is often called Flame Rectification.

8.19 ***Scanning type sensors*** detect the presence of radiant energy produced by a burning fuel and, through an electronic circuit, indicate the presence of a flame. There are three types that are most generally used:

(a) A ***Visible Light Detector*** (Caesium Phototube), which is used only with oil since gas does not have sufficient luminosity to properly activate the phototube.

(b) An ***Infra-Red Detector*** (Lead Sulfide Photocell), which may be used for oil or gas but has the disadvantage of possibly being activated by hot boiler refractory if not properly installed.

(c) An ***Ultra-Violet Detector,*** which may be used for oil or gas but has a disadvantage in that it will respond to the spark of electric ignition even though it will not respond to hot refractory.

Programmer and Flame Sensor Requirements

8.20 Programmer and flame sensing requirements for any particular heating plant depend on the capacity of the burner and the type of fuel burned.

8.21 ***Gas fuel burners with up to 200,000 Btu/hr input*** require a flame sensor of the thermocouple flame rod or ultra-violet scanning type. The sensor used shall, upon failure of the monitored flame, cause the automatic fuel shutoff valves in the main burner gas line to close.

8.22 ***Gas fuel burners with over 200,000 Btu/hr input*** require a flame sensor that will supervise the pilot and the main flame. The sensor may be a scanning type sensor, either an infra-red or an ultra-violet detector, or a flame rod sensor. The sensor and programmer require a "safe start" circuit check before the start of each cycle, a flame response of one to four seconds, and shall not attempt to re-light after a flame failure. All flame failure control installations should be installed and tested in accordance with the manfacturer's instructions. All installations shall have U.L. or F.M. listing.

8.23 On power gas burners, the programming equipment shall provide the following:

(1) A safe start check of the programmer and sensor before every cycle. For additional safety, the programmer may have the safe start check plus a continuous check of both the programmer and sensor during burner on cycle.

(2) Proven low fire start when low fire start is provided.

(3) Preignition purging. The air flow should be supervised during the entire prepurge period by a pressure switch wired into the operating circuit so as to prove air flow during the first 10 seconds of prepurging and continuously thereafter, and to shut down automatic fuel shutoff valves in the event of low air flow. The prepurge period shall provide a minimum of four air changes of the total air quantity including the combustion chamber, boiler passes, and breeching or shall last for a period of 60 seconds, whichever is shorter. In no case shall the purge air flow rate be less than 1/3 of the high fire flow rate.

(4) Timed trial for ignition of pilot and main flame. This time interval shall be as short as practical and shall not exceed 15 seconds for the main flame and 10 seconds for the pilot.

(5) The post-purge period should be as short as possible but sufficient to remove unburned fuel from the burner and fuel piping.

8.24 On atmospheric gas burners that have programmed ignition of the main flame, the programmer shall provide:

(1) A safe start check of the programmer and sensor before each cycle.

(2) A trial for ignition that does not exceed 15 seconds.

8.25 If an automatic damper is installed in the boiler breeching, integral interlocks should be wired into the control circuit to assure proper purge and safe light-off of the burner. Provision shall also be made to prevent burner operation if either fuel valve operator fails to go to the closed position on the off cycle. If this should occur, the automatic damper must stay in the open position.

8.26 ***Oil burners using light oil and having up to 20 gph capacity*** require a flame sensor of the scanning type. The sensor and programmer require a flame failure response of one to four seconds and shall not attempt to re-ignite after a flame failure. The programmer trial for ignition should not exceed 15 seconds. Where low fire start is provided, the burner control shall be proved in that position before ignition can take place. Ignition should not take place with flow rate above 10 gph. The flow of combustion air is monitored by a pressure switch in all burners with a flow rate over 10 gph and in any heating plant where a separate fan is installed.

8.27 ***Oil burners using heavy oil or light oil and having over 20 gph capacity*** require a flame sensor that will supervise the pilot and the main flame. The gas pilot sensor may be a scanning type sensor, either an infra-red or an ultra-violet detector, or flame rod sensor. The oil pilot and the main flame sensor may be any of the three scanning type sensors; visible light, infra-red, or ultra-violet. The sensor and programmer require a safe start circuit check before the start of each cycle. If an ultra-violet sensor is used, it may be equipped with a continuous check system. The programmer will not permit the burner to re-ignite after a safety shutdown. The programmer also provides the following:

(1) Proven low fire start.

(2) Prepurge of combustion chamber to affect four air changes or run for 60 seconds,

whichever is shorter. Prepurge is not required for installations which have only primary air provided by the burner fan.

(3) Air flow supervision provided by a pressure switch wired into the operating circuit to prove air flow during the first ten seconds of prepurging and continuously thereafter and to shut down automatic fuel valves in the event of low air flow.

(4) Time trial of 10 seconds for pilot ignition.

(5) Proof of pilot ignition. Safety shutdown in case of pilot failure.

(6) Time trial for main flame ignition. 30 seconds for heavy oil, and 15 seconds for light oil.

(7) Proof of main flame ignition.

(8) Interruption of pilot flame.

(9) Supervision of main flame with 2 to 4 second shutdown in the event of main flame failure.

(10) Shutdown by operating controller.

(11) Post-purge of 15 to 30 seconds to remove unburned fuel from cup or nozzle.

Draft Controllers

8.28 Draft controllers for atmospheric burners are divided into two groups: natural and mechanical. The natural draft controllers are usually barometric dampers. These are weight balanced to maintain a steady over-the-fire draft by opening to admit more boiler room air if the draft up the chimney increases due to barometric conditions, etc. It is most important that these be installed as per manufacturer's recommendations and the weights adjusted to maintain the proper over-the-fire draft. On large boilers when the draft is excessive, a mechanical damper may be used. This damper positions itself by sensing the over-the-fire draft. The damper must be electrically wired to be open to the set position before the starting of the burner. If the draft is below the minimum set level, this control will not allow the main fuel valve to open. This arrangement is also used with a mechanical induced draft fan. The mechanical induced draft fan starts with the burner and maintains a steady over-the-fire draft. The fan should be adjusted to provide the recommended over-the-fire draft. It is most important that the controls be wired so that the burner will shut down in case of a failure of the induced draft fan.

8.29 Draft controls for forced draft burners are sensitive pressure controllers that measure the over-the-fire draft. If there is insufficient draft, the control will not allow the burner to fire or if draft is lost during firing the control will shut down the burner.

Oil Preheaters

8.30 The ***oil preheaters*** most commonly used on low-pressure heating boilers are electrically operated. These have a thermostat with a dial setting to select the desired temperature. On many oil burning units the oil preheater is an integral part of the burner. Other types of preheaters use steam or hot water for the heating medium. This type of preheater would be used when large quantities of oil are to be heated. On either the steam or the hot-water units, caution must be taken to ensure that oil does not enter the condensate system and contaminate the boiler. If this should happen, the boiler may require cleaning. The oil coats the heat transfer surfaces and could possibly cause tube burnouts or other damage to the boiler. Hot-water preheaters can effect closer control over the oil temperature than steam heaters. Steam preheaters present a problem in that they may raise the temperature of the fuel oil to the flash point if the regulating valve fails since steam at only 5 psi has a temperature of 227°F. Another disadvantage with steam preheaters is the problem of preheating the oil for start-up if the steam load is lost in the plant. Preheaters should have thermometers on the inlet and outlet pipes.

OPERATING CONTROLS

Pressure or Temperature Controls

8.30 The operating pressure or temperature control is the basic device for controlling the burner. On small boilers the operating control might be a thermostat located in the most populous space controlling the burner with a pressure or temperature control located on the boiler to prevent overfiring. Larger boilers will be controlled solely by pressure or temperature controls that keep the boiler operating between certain set points. In areas where the outdoor temperatures fluctuate through a wide range during certain seasons of the year, an outdoor thermostat may be used. This control shuts down the boiler when the outdoor temperature rises above a set point. On hot-water boilers an outside thermostat is often used to modulate the boiler water temperature, increasing it as the outside temperature goes down. The steam pressure or water temperature controls must not have a range greater than the maximum allowable working pressure or temperature of the boiler. This would be 15 psi for steam and 250°F for hot water.

8.31 Firing rate controls may be installed on some burners. The controls may be either two-position, low-fire and high-fire, or may provide full modulation of the burner flame. They normally utilize a pressure or temperature sensing device mechanically linked to a potentiometer connected electrically to a modulating motor. A movement of the pointer on the potentiometer causes a corresponding movement in the motor. The motor is mechanically linked to the air control and fuel metering device on the burner. All burners so equipped should have an auxiliary switch (end switch) connected electrically to the combustion control system to prevent starting the burner in other than low fire position. These modulation controls should be set to the design operating pressure or temperature of the building, ie, the minimum steam pressure or water temperature necessary to heat the building. As the boiler pressure or temperature increases, the burner motor will begin to modulate toward low fire.

Water Feed Controls

8.32 ***Pressure reducing valves*** (Fig. 23) are installed in the make-up water lines to the hot water boiler to maintain the desired hydrostatic pressure in the boiler. The valve, which has an adjustable pressure setting, will maintain pressure in the boiler whether there is flow in the system or not. If there is a loss of water in the system, the hydrostatic pressure will fall and the valve will open to admit water until pressure is restored.

8.33 ***Float type water feeders*** are available in units combined with a low water fuel cut-off switch as illustrated in Fig. 24 or as a single water feed device. Water feeders utilize a float that is linked to the water feed valve and, on the combined units, to an electric switch. The float moves with the change of water level in the boiler, opening the water feed valve to restore the water level. The combined unit is used on steam boilers. Hot water boilers do not normally use the unit with the cut-off switch.

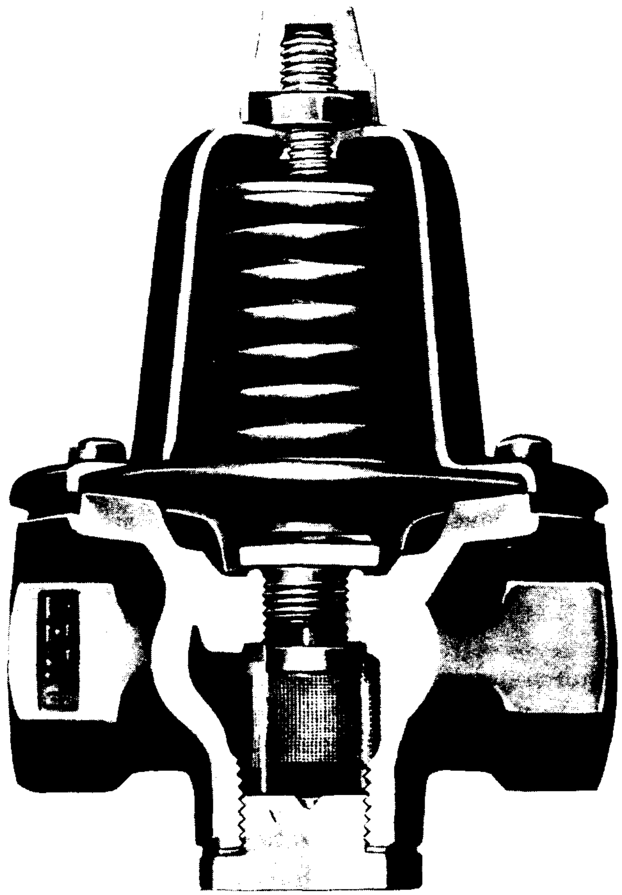


Fig. 23—Pressure Reducing Valve, Internal View Showing Strainer (Bell And Gossett Co.)

8.34 On steam boilers, as the water level falls the automatic water feed valve is opened to restore the water level. If the water level, for some reason, should continue to fall, the low water fuel cutoff switch will operate. This switch is not the low water limit control (see 8.48 and 8.49) but is in the operating control circuit of the programmer or flame control relay which will allow the burner to restart if the water level should be restored. The unit should be located so the low water fuel cutoff switch will operate when the water level is 2 inches above the lowest safe water level in the boiler.

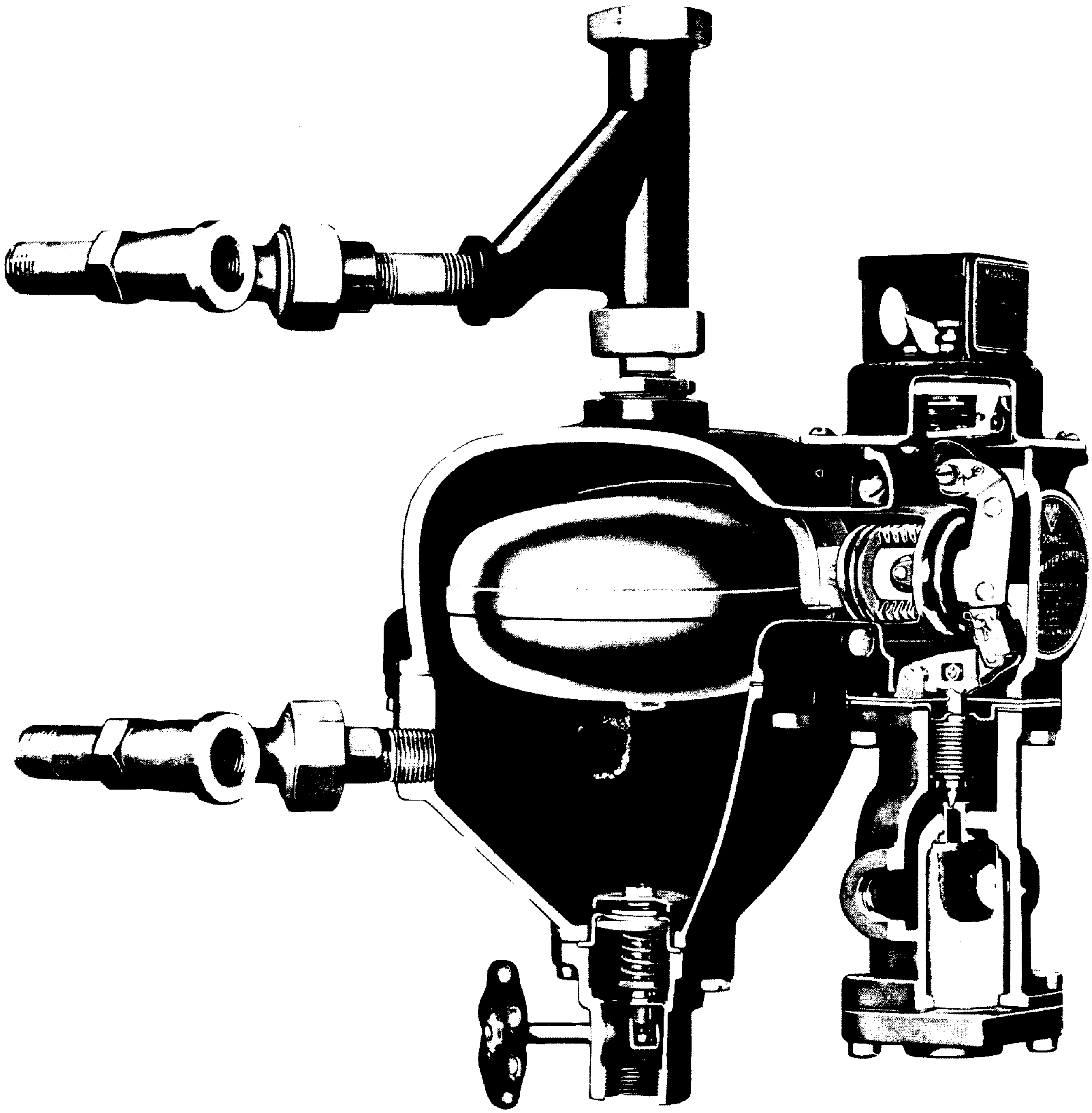


Fig. 24—Combination Low Water Fuel Cutoff And Boiler Water Feeder (McDonnell and Miller, Inc.)

8.35 A float actuated switch device similar to the low water fuel cutoff switch is used on some boilers to activate a condensate return pump when the boiler water level falls. This device is called a pump controller.

8.36 On hot water boilers, an automatic water feed is installed at a water level one inch below the level that actuates the low water limit control. This will maintain a water level in the boiler sufficient to prevent tube damage.

Condensate Return Pumps

8.37 Condensate return pumps are used on either one- or two-pipe steam systems to return the condensate to the boiler where it cannot be returned by gravity. Return pumps (Fig. 25) consists of a reservoir, a pump, and a float operated switch for starting the pump motor. Condensate flows by gravity into the pump reservoir, which is vented to the atmosphere. As the condensate accumulates, the float is raised and after it has reached a certain level, the arm to which the float is attached trips the switch and starts the pump motor to pump the condensate into the boiler. A check valve on the pump discharge prevents the condensate from draining back into the reservoir when the pump is stopped. The inlet to the pump reservoir should have a strainer to remove scale, rust, etc.

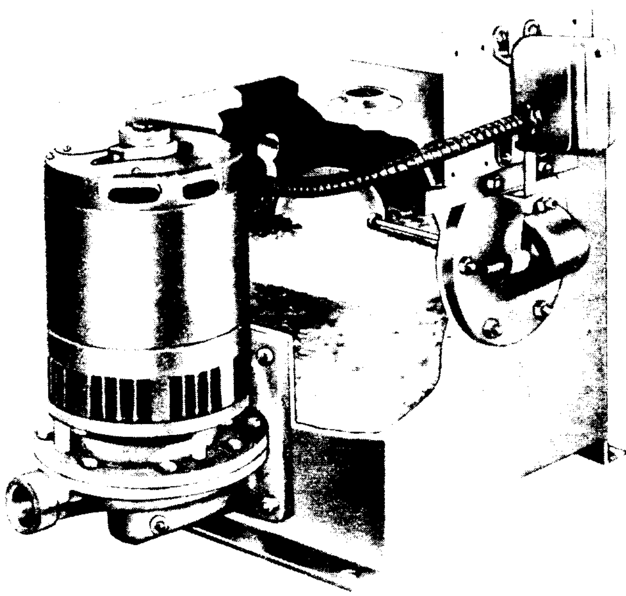


Fig. 25—Condensate Return Pump (Dunham-Bush, Inc.)

8.38 Because most boilers are equipped with combination water feeder and low water fuel cutoffs, the condensate return pump system often causes a fluctuation of the boiler water level in changeable weather. If there is a lag in the condensate returning to the pump reservoir, the water feeder will make up fresh water in the system. After the condensate is returned to the reservoir, the float action will pump the condensate into the boiler regardless of the boiler water level. If the boiler is idle the condensing boiler steam will create a vacuum in the boiler and frequently will force open the feed valve.

8.39 This vacuum condition can be prevented by installing a vacuum breaker on the boiler. It can be installed on a tee with the pressure gauge or on some other direct opening to the boiler drum except the safety valve opening.

8.40 A condensate collecting tank will eliminate the fluctuating water level problem. The condensate flows by gravity into the tank, which is equipped with a pump that is electrically connected to a pump controller on the boiler. The controller maintains a constant level by starting the pump if the water level falls in the boiler. The tank holds sufficient condensate to prevent overfilling the boiler. Any fresh make-up water is introduced into the tank, not the boiler. This prevents thermal shock because the cold make-up is mixed with the relatively cool condensate rather than with the higher temperature water in the boiler.

Vacuum Return Pumps

8.41 The vacuum return pump (Fig. 26) is used in larger buildings where the return of condensate presents a problem. A return pump consists of a reservoir with two compartments, a pump, equipment for starting and stopping the pump, and a means for producing a vacuum. Condensate flows into the lower compartment of the reservoir by gravity, assisted at times by the vacuum in the return or lower tank. The pump is started or stopped by the float position in the lower tank or by the vacuum in the lower tank. The pump usually cuts in at a 2-inch vacuum and shuts off at a 7-inch vacuum. The water is discharged to the boiler by the action of another float in the upper chamber.

8.42 The use of a vacuum pump on a heating system does not mean that the system will be operated at a vacuum, but only the returns. By pulling a vacuum in the returns, the air is removed permitting a quicker return of the condensate to the pump. Any heating units not in use at the time the air is removed are also partially evacuated permitting the steam to more quickly fill these units when the supply valve is turned on. Any entrapped condensate in the heating

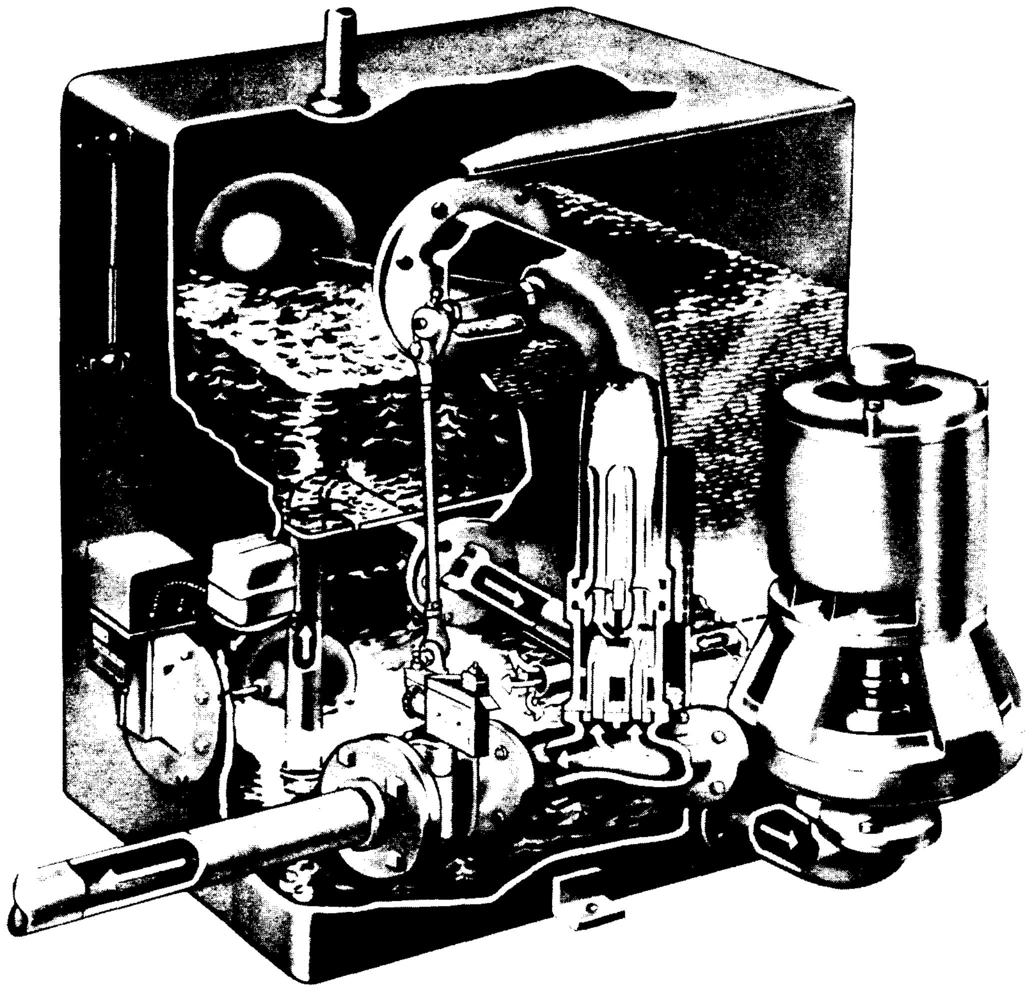


Fig. 26—Vacuum Return Pump (Dunham-Bush, Inc.)

units or in the return piping is also quickly removed due to the vacuum created. Because there is a partial vacuum in the returns after the traps, re-evaporation of a certain percentage of the water will take place.

Circulators

8.43 Circulators used on hot-water heating systems vary from small fractional horsepower pumps handling a few gallons per minute to very large units handling several hundred gallons per minute. They are basically centrifugal pumps (Fig. 27) especially designed for hot-water service. One or more circulators may be employed on each system, depending on the size of the building, desired zoning, method of heat distribution, etc. Control of the circulator may be by room thermostat, boiler water thermostat, outdoor thermostat, or other similar device.

LIMIT CONTROLS

8.44 Each boiler or furnace must be equipped with a manual reset high limit pressure or temperature control. This limit control is not wired into the operating circuit of the programmer but is wired so that activation of the control will shut off power to the control system. *The limit control* must be set to operate at a point above the cut-out point of the operating control. For installations of more than one boiler where the operating control is on the header, two limit controls are installed on each boiler.

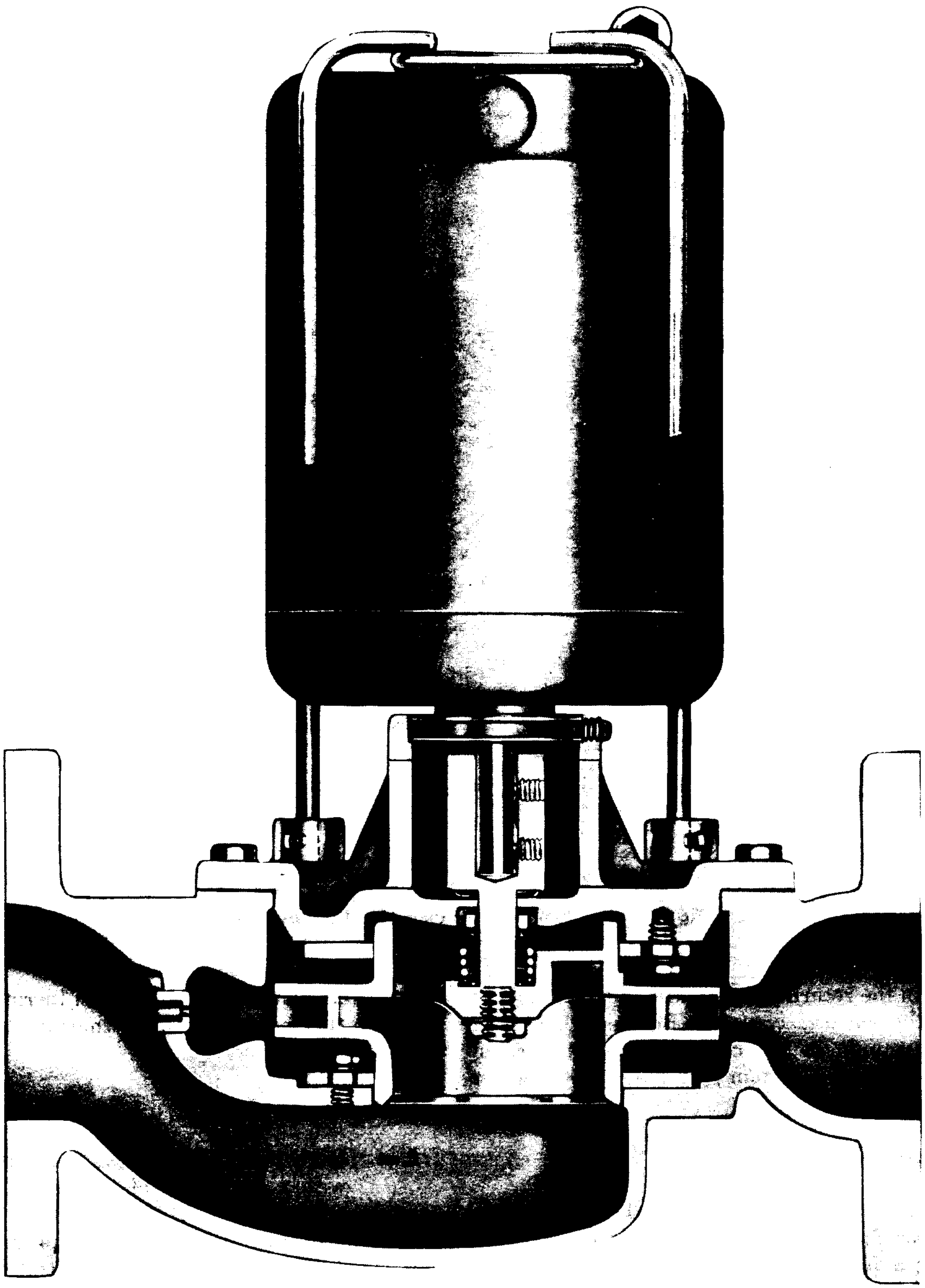


Fig. 27—Hot Water Circulator (Dunham-Bush, Inc.)

8.45 Pressure activated limit controls should be connected directly to the boiler shell utilizing a separate antisiphon device or "pig-tail" for each control as shown in Fig. 28. There must not be any shutoff valve in the pressure sensing lines to the controls. The ***right*** and ***wrong*** in the figure involves possible tilting of the mercury switch in the limit control due to expansion or contraction in the siphon loop if this loop is installed parallel to the front of the switch. It is important to mount the limit control perpendicular to the siphon loop in order to remove the possibility of false operation.

8.46 Temperature activated limit controls for hot water boilers should be of the insertion type with separable well sockets mounted in the boiler shell for the temperature sensing element. Devices with capillary elements between the sensing element and the control should not be used.

8.47 Space heating furnaces require that a limit control be installed on the discharge plenum. The control shall be set to operate at a temperature of not more than 75°F above the normal discharge temperature.

Low Water Fuel Cut-off Limit Controls

8.48 ***Low Water Fuel Cut-off Limit Controls*** provide protection against hazardous low water conditions in heating boilers. Insurance company records indicate that more boiler explosions result from low water than any other cause.

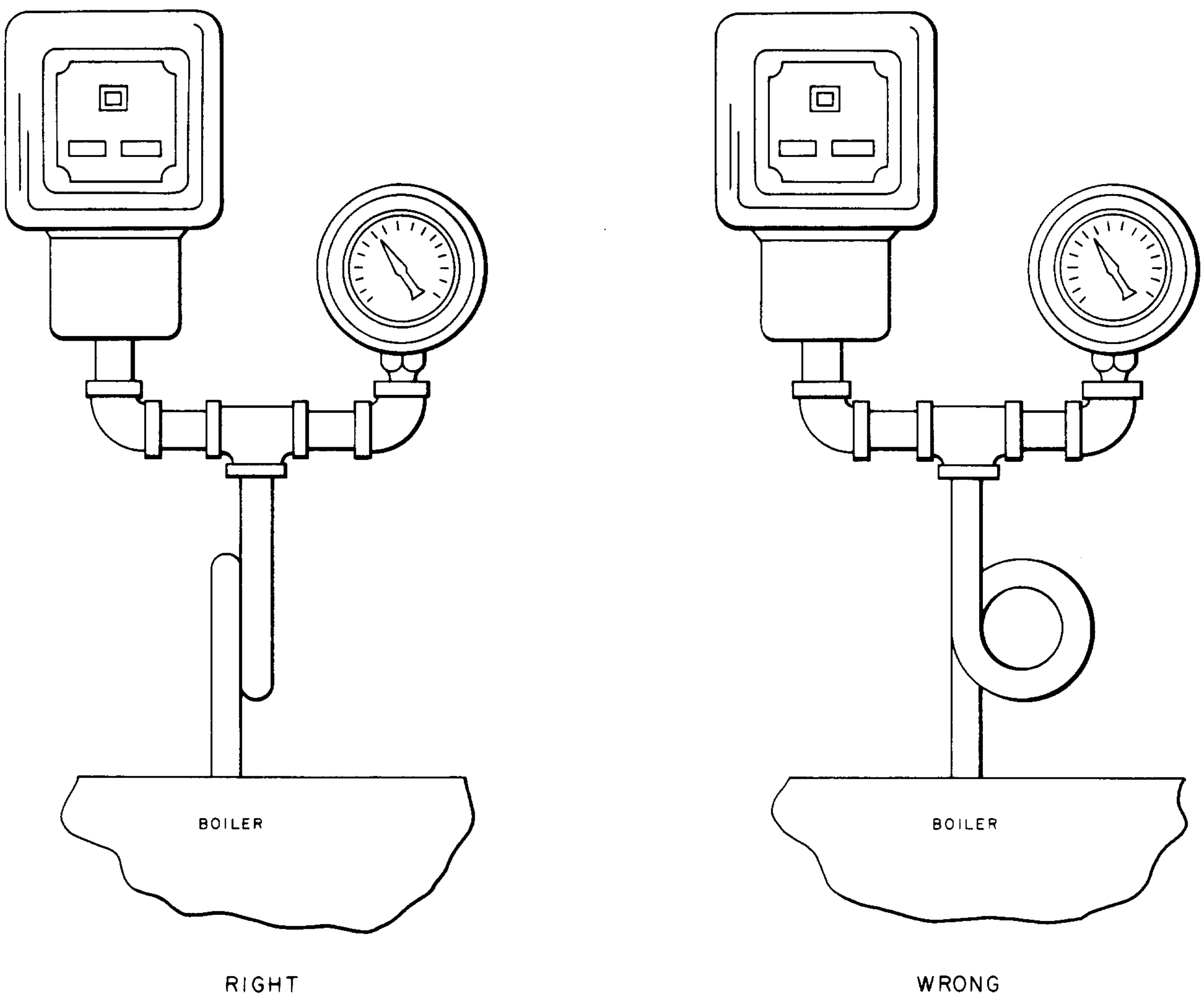


Fig. 28—Pressure Control Installation (The Minneapolis-Honeywell Regulator Co.)

8.49 Low water limit controls may be generally divided into two classes, ***float type*** and ***probe type.*** The float type maintains electrical continuity by actuating an electrical switch by the level action of a float that positions itself with respect to changes in the boiler water level. If the water should fall below a certain level, the switch will open. The probe type maintains electrical continuity through two electrodes being in contact with the boiler water. If the water level should fall enough to break contact with one of the electrodes, the control circuit will open. If the control circuit opens, the system will shut down. The low water limit controls must be reset manually. Float-type low water fuel cut-off controls are illustrated in Fig. 29 and 30.

8.50 On steam boilers, the low water fuel cut-off limit control should shut down the system when the water level falls to a point between the level at which the low water fuel cut-off switch will operate and the lowest safe water level.

8.51 On hot water boilers, the low water fuel cut-off limit control should shut down the system when the water level in the boiler falls to a level two inches above the lowest safe water level.

SAFETY CONTROLS

Safety and Relief Valves

8.52 The safety or relief valve (or valves) is the final line of protection against over-pressure in the boiler. This is the most important single safety device on any boiler. The design and construction features of low-pressure safety and low-pressure relief valves, commercially available and listed by the National Board of Boiler and Pressure Vessel Inspectors, have been carefully studied, and safety and relief valves of various manufacturers have been listed in P.E.M. 9803 dated May 20, 1966. P.E.M. 9803 supplements the original recommendations of P.E.L. 7129. Detailed specifications and testing procedures are covered in Section 760-540-150 and 760-540-151.

8.53 Safety valves (Fig. 31 and 32) are associated with steam boilers and are characterized by a full-open pop-action.

8.54 Relief valves (Fig. 33) are associated with hot water boilers and are characterized by pop-action with a further increase in lift as pressure increases over popping pressure.

9. ACCESSORIES

Compression Tanks

9.01 Compression tanks and expansion tanks are used on hot-water heating systems (Fig. 34) to allow for the expansion of the water when it is heated. In a compression tank system, an air cushion in the tank is compressed by the expanding water. Some systems, because of local ordinances, have an atmospheric tank with a water level control for boiler water make-up.

Traps

9.02 ***A steam trap*** is a device put on the outlet side of radiators or other heating units of a two-pipe steam system to provide free exit for the condensate and air but to prevent the passage of steam. There are three general types of steam traps: thermostatic, float, and inverted bucket.

9.03 There are three varieties of ***thermostatic traps:***

(1) Those depending upon the deformation of a bimetal strip.

(2) Those which depend upon the expansion of a liquid.

(3) Those which depend on the vaporization of a liquid.

Small thermostatic traps are usually rated in square feet of EDR. One square foot of EDR is taken to mean 0.25 db of water per hour. These traps (Fig. 35) are usually used on radiators, converters, and any other two-pipe steam equipment when there is sufficient time available to permit the condensate to cool to the opening temperature of the trap before the heating unit fills with water.

9.04 A ***float trap*** (Fig. 36) does not depend upon the temperature of the condensate for operation. The action is through a float only. The thermostatic element is added to the trap to get rid of the air accumulated during the heating up period. The ***float and thermostatic trap*** (Fig. 37) can be used for all purposes for which a plain thermostatic trap is used and for some installations

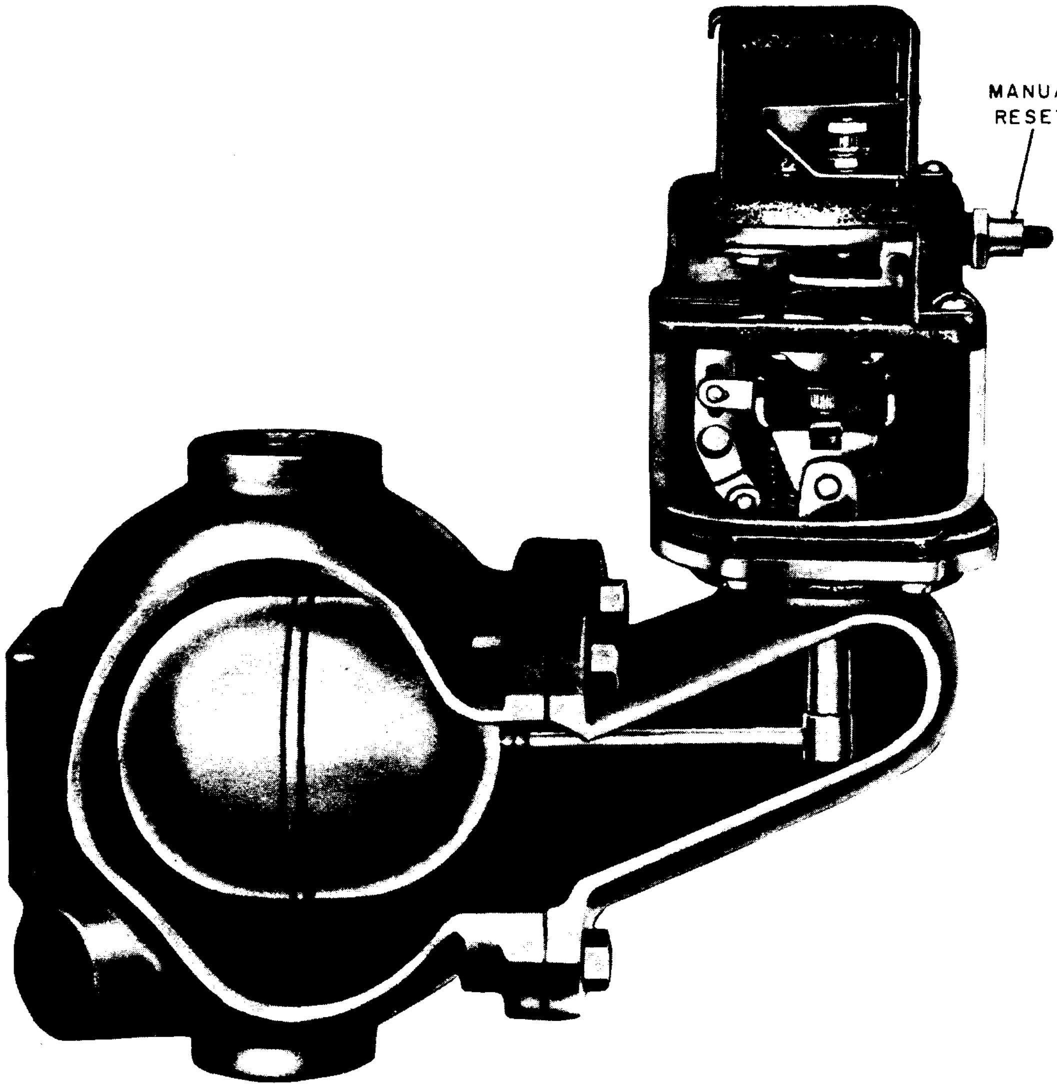


Fig. 29—Low Water Fuel Cutoff With Manual Reset—Mechanical Switch (McDonnell and Miller, Inc.)

on which a thermostatic trap would not be suitable. It is ideal for dropping a supply main or a downfeed riser into the dry return of a two-pipe system. The plain float trap can only be used where the relief of air is not a problem.

9.05 ***Inverted bucket traps*** (Fig. 38) do not operate on the temperature of the condensate, but use an inverted bucket that raises and lowers as steam enters and condenses. This means that the condensate is discharged intermittently. A bucket trap is used on unit heaters, steam coils, cooking equipment, etc. It is never used where the load variation is great.

9.06 A dirt strainer must always be placed in the line ahead of the float and thermostatic trap or the bucket trap.

Valves

9.07 The valves most commonly used on heating plants in the Bell System are the globe, angle, gate, cock, and check types of valves which are illustrated in Fig. 39. Uses for the various types of valves are as follows:

(a) ***Globe valves*** are used for throttling. These valves cause the fluid to change direction

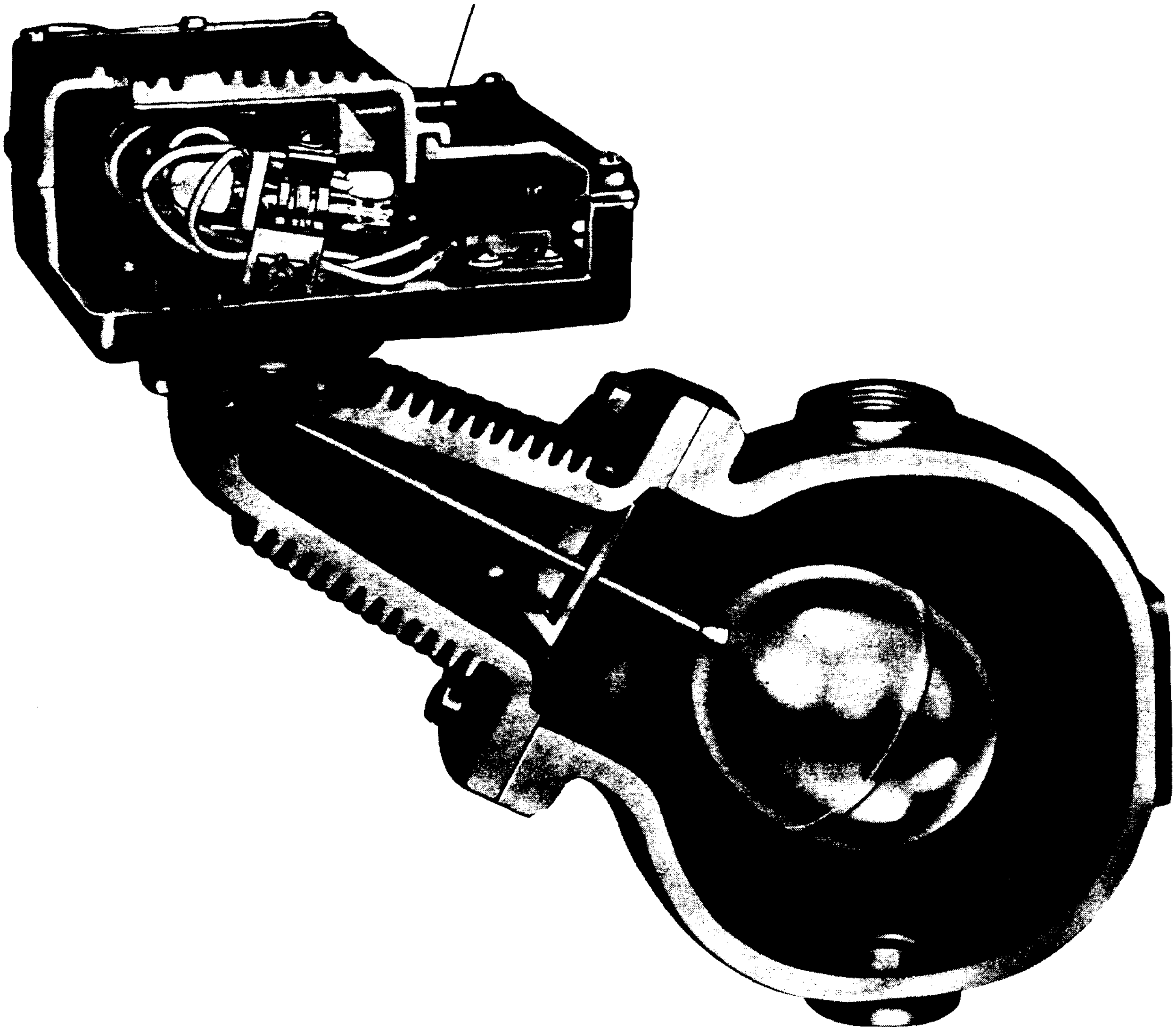


Fig. 30—Low Water Fuel Cutoff With Manual Reset—Mercury Switch (McDonnell and Miller, Inc.)

and, consequently, offer considerable resistance to flow, even in the fully open position.

(b) ***Angle valves*** are similar to globe valves except that the outlet face is at a 90 degree angle to the inlet face. An angle valve takes the place of a globe valve on an elbow.

(c) ***Gate valves*** are used where service demands that the valve be fully open or entirely closed. They should not be used for throttling.

(d) ***Cock valves*** are used as throttling devices in piping branches to balance the flow of water in a system. They are usually set at the time a system is installed, and the setting does not need to be changed unless the system is modified. Many of these valves require lubrication and should be checked on a routine basis.

(e) ***Check valves*** are used to prevent back flow. The basic principle of all check valves is that a reversal of flow will close the valve.

Fuel Storage and Supply Systems

9.08 ***Oil burning equipment*** requires a fuel storage tank of adequate size. This tank

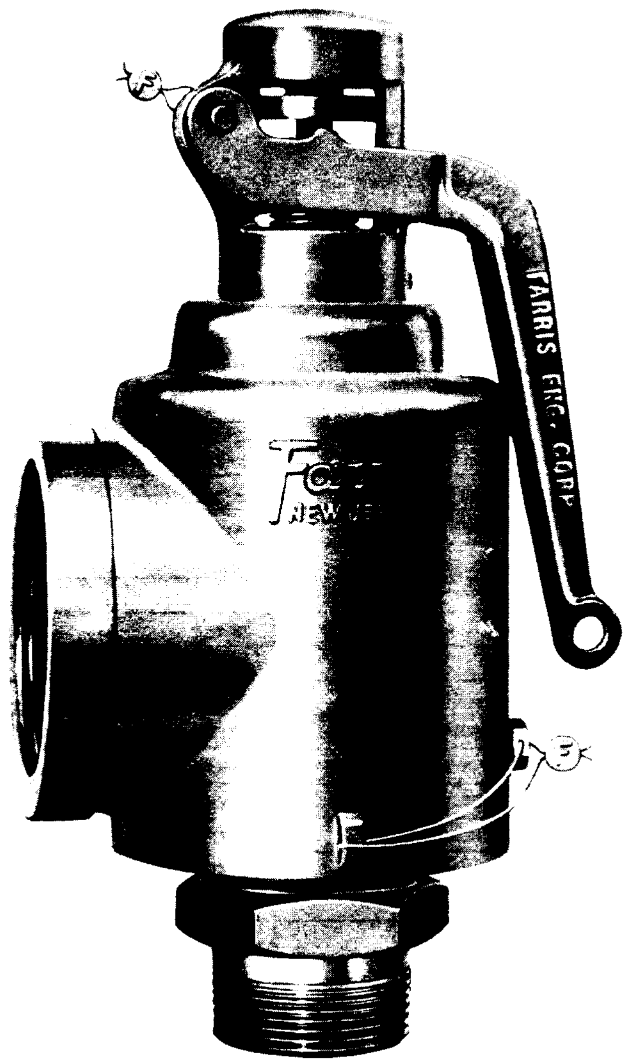


Fig. 31—Safety Valve (Farris Engineering Corporation)

may be mounted adjacent to and slightly higher than the burner, providing gravity flow, or buried or mounted below the burner requiring the fuel to be pumped to the burner. All oil pumps deliver more oil to the burner than is needed. The extra oil is delivered back to the tank (two-pipe system) or to the suction side of the pump (single-pipe system). This is the basic difference between one and two-pipe systems. All underground installations must have a two-pipe system, ie, the return line emptying into the tank. This system has the advantage in a preheated oil system of keeping the oil in the tank warm.

9.09 The vent pipe on the tank must be adequately sized to prevent backup and spillage when filling the tank. The vent must not under any circumstances be tied in with the fill pipe but must be located in sight of the fill pipe. If the tank is below the burner, the supply line to the burner and the return line must be equipped with a check valve located as close to the burner as possible. The use of a foot valve at the end of the suction line inside the tank may be avoided by the installation of a check valve on the horizontal portion of the line where it enters the tank.

9.10 A vacuum gauge installed in the oil suction line is very helpful in locating tank or suction line troubles and also in determining the quantity of fuel in the tank. The vacuum reading increases as the level in the tank falls.

Oil Supply Pumps

9.11 Gear type oil supply pumps are used for transferring the oil to the burner. The discharge pressure depends on the type of fuel burning equipment. These are normally classifed into two types: the single-stage and two-stage pumps. ***The single-stage pump*** uses the same set of gears for suction and pressure delivery of the oil. ***The two-stage pump*** has two sets of gears, one for pulling the oil from the tank and the other for delivering it under pressure to the nozzle. The single-stage pump is normally used with single-line gravity fed system. The two-stage pump is used where the tank is below the burner. All pumps should be equipped with a discharge pressure gauge.

10. REFERENCES

10.01 The following references were used in preparing this section.

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Shields, C. D. ***Boilers,*** McGraw-Hill Book Company, New York, 1961.

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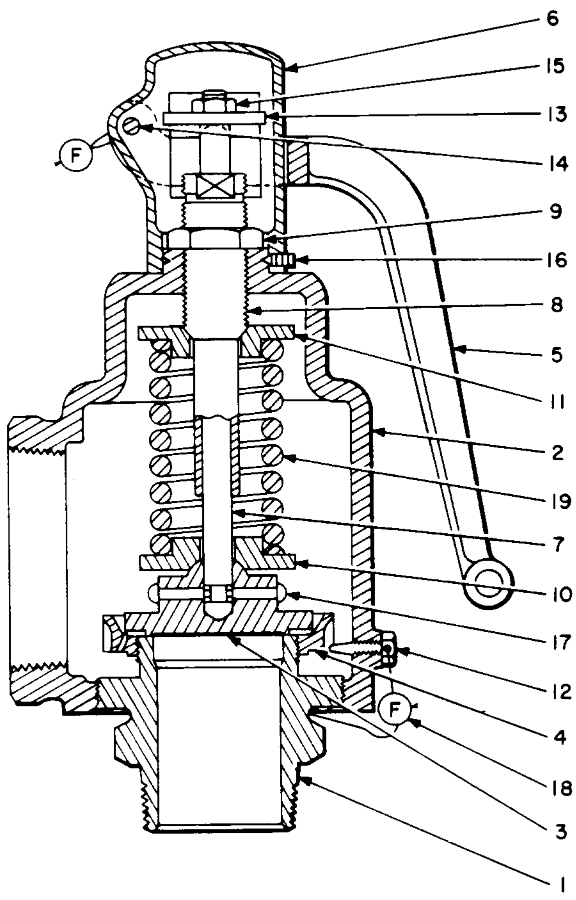

BILL OF MATERIALS		
ITEM	DESCRIPTION	MATERIAL
1	VALVE BODY	BRONZE
2	BONNET	CAST IRON
3	DISC	BRONZE
4	BLOW DOWN RING	BRONZE
5	TEST LEVER	MALL. IRON
6	CAP	MALL. IRON
7	STEM	STAINLESS STEEL
8	SPRING ADJUSTING SCREW	BRASS
9	JAM NUT	BRASS
10	SPRING BUTTON-LOWER	STEEL-CAD. PLTD.
11	SPRING BUTTON-UPPER	STEEL-CAD. PLTD.
12	BLOW DOWN RING LOCK SCREW	BRASS
13	STEM TEST WASHER	STEEL-CAD. PLTD.
14	BUTTON HEAD RIVET	STEEL
15	JAM NUT-STEM	STEEL-CAD. PLTD.
16	SET SCREW	STEEL-CAD. PLTD.
17	DRIVE SCREW	STEEL-CAD. PLTD.
18	WIRE SEAL	LEAD
19	SPRING	CARB. STL.-RUST PROOF

Fig. 32—Safety Valve, Typical Construction (Farris Engineering Corporation)

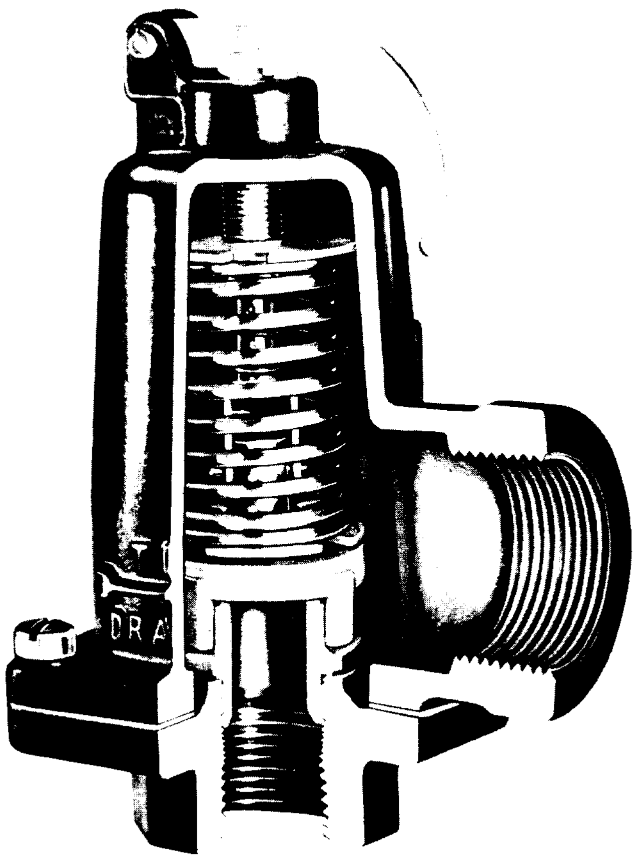

Fig. 33—Relief Valve (McDonnell and Miller, Inc.)

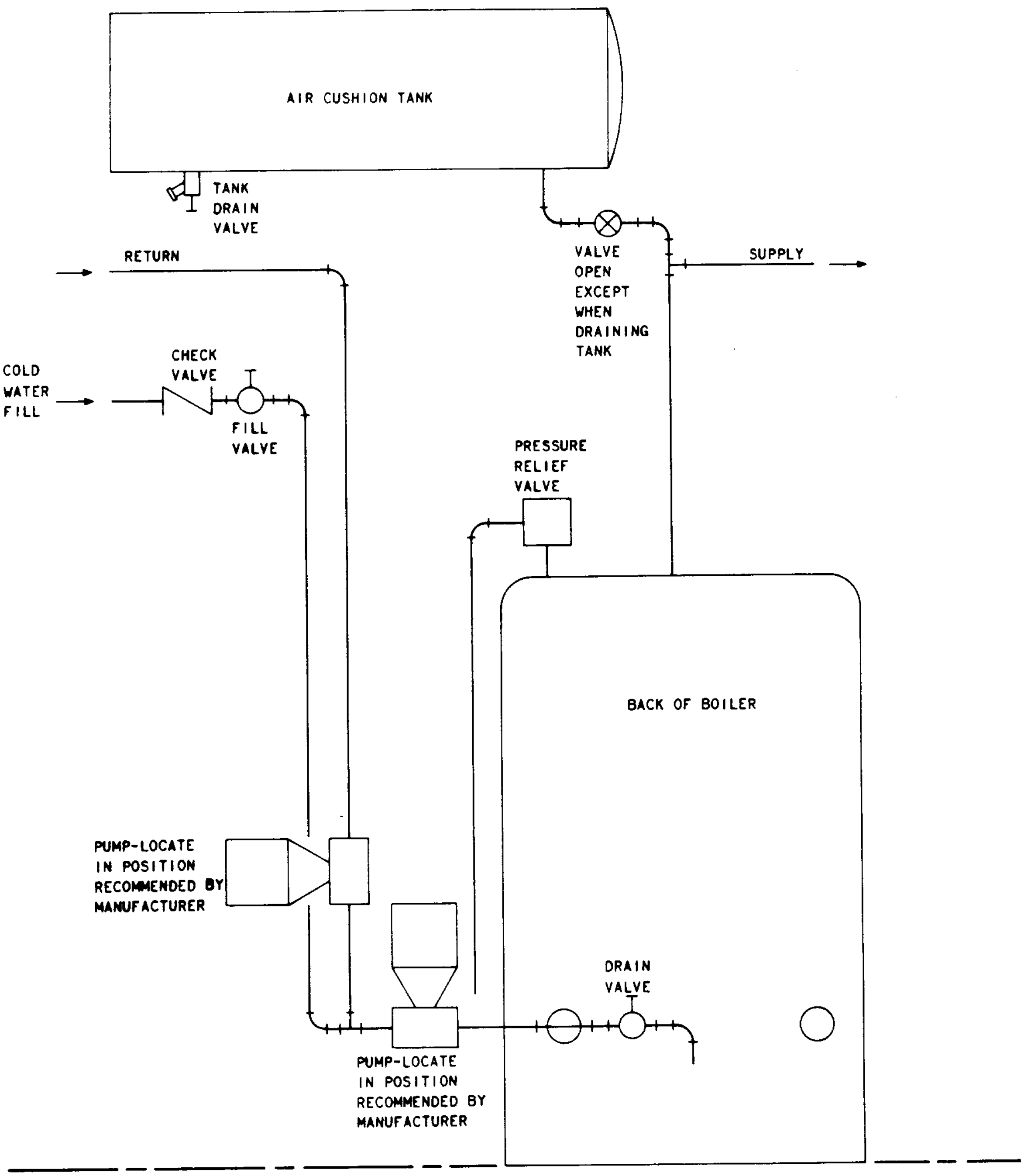

Fig. 34—Compression (Expansion) Tank (Reprinted with Permission ASHRAE Guide and Data Gook, 1961)

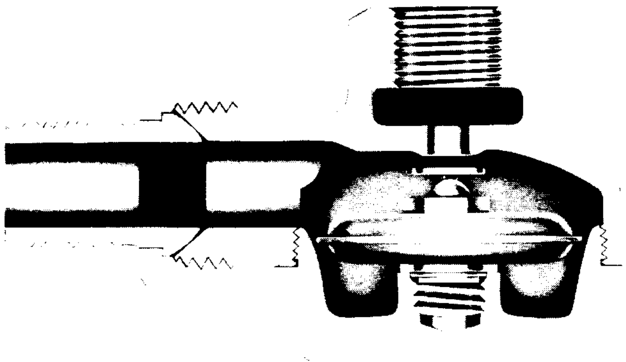

Fig. 35—Thermostatic Trap (Dunham-Bush, Inc.)

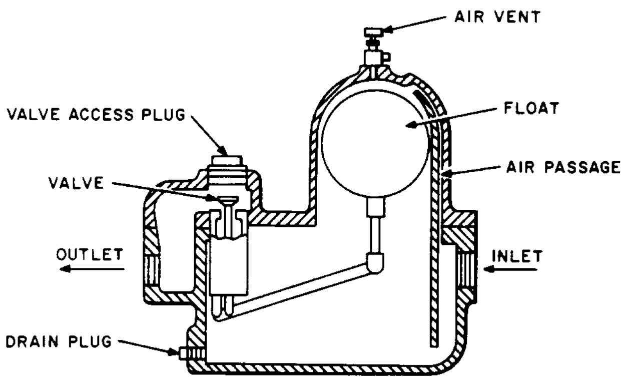

Fig. 36—Float Trap (Reprinted with Permission ASHRAE Guide and Data Book, 1962)

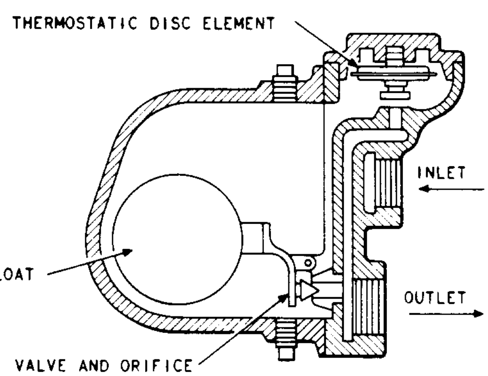

Fig. 37—Float and Thermostatic Trap (Reprinted with Permission ASHRAE Guide and Data Book, 1962)

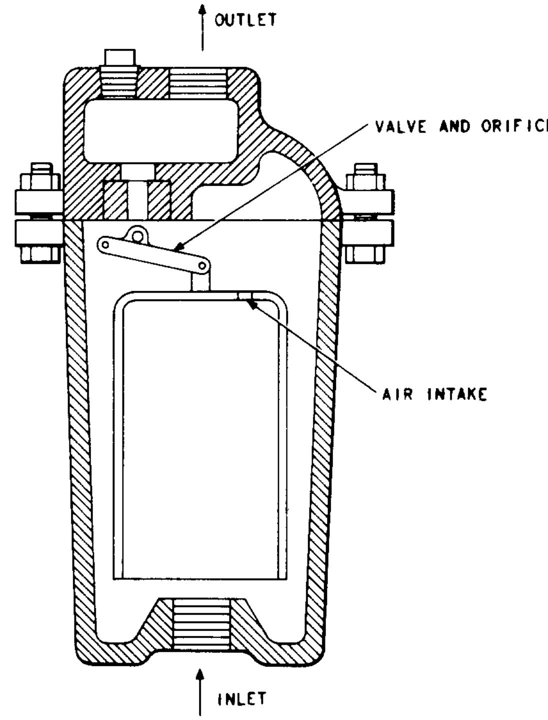

Fig. 38—Inverted Bucket Trap (Reprinted with Permission ASHRAE Guide and Data Book, 1962)

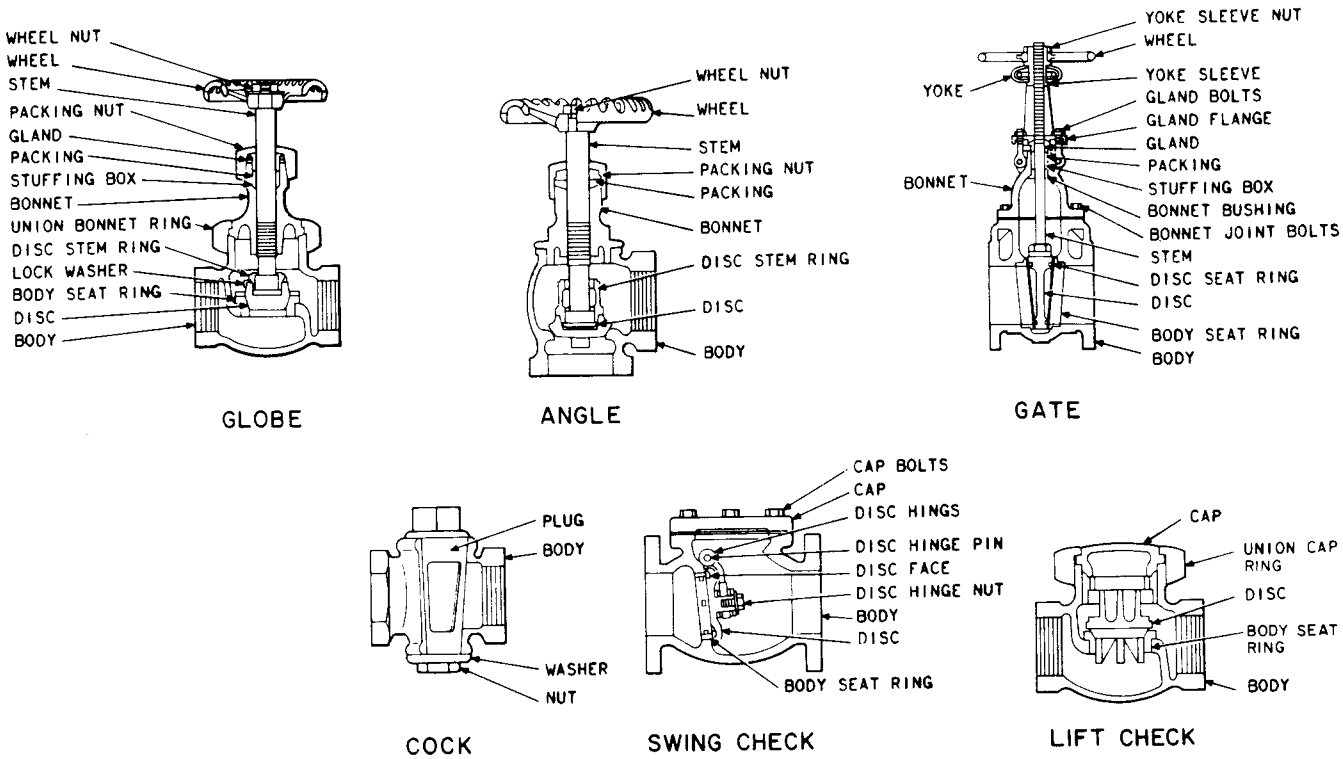

Fig. 39—Valve Types (Crane Co.)