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HVAC Fundamentals Volume 2

Heating System Components, Gas and Oil Burners, and Automatic Controls

All New 4th Edition

James E. Brumbaugh

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For Laura, my friend, my daughter.

Contents

Introduction

The purpose of this series is to provide the layman with an introduction to the fundamentals of installing, servicing, troubleshooting, and repairing the various types of equipment used in residential and light-commercial heating, ventilating, and air conditioning (HVAC) systems. Consequently, it was written not only for the HVAC technician and others with the required experience and skills to do this type of work but also for the homeowner interested in maintaining an efficient and trouble-free HVAC system. A special effort was made to remain consistent with the terminology, definitions, and practices of the various professional and trade associations involved in the heating, ventilating, and air conditioning fields.

Volume 1 begins with a description of the principles of thermal dynamics and ventilation, and proceeds from there to a general description of the various heating systems used in residences and light-commercial structures. Volume 2 contains descriptions of the working principles of various types of equipment and other components used in these systems. Following a similar format, Volume 3 includes detailed instructions for installing, servicing, and repairing these different types of equipment and components.

The author wishes to acknowledge the cooperation of the many organizations and manufacturers for their assistance in supplying valuable data in the preparation of this series. Every effort was made to give appropriate credit and courtesy lines for materials and illustrations used in each volume.

Special thanks is due to Greg Gyorda and Paul Blanchard (Watts Industries, Inc.), Christi Drum (Lennox Industries, Inc.), Dave Cheswald and Keith Nelson (Yukon/Eagle), Bob Rathke (ITT Bell & Gossett), John Spuller (ITT Hoffman Specialty), Matt Kleszezynski (Hydrotherm), and Stephanie DePugh (Thermo Pride).

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James E. Brumbaugh

About the Author

James E. Brumbaugh is a technical writer with many years of experience working in the HVAC and building construction industries. He is the author of the *Welders Guide*, *The Complete Roofing Guide*, and *The Complete Siding Guide*.

Chapter 1

Oil Burners

An oil burner is a mechanical device used to prepare the oil for burning in heating appliances such as boilers, furnaces, and water heaters. The term *oil burner* is somewhat of a misnomer because this device does not actually burn the oil. It combines the fuel oil with the proper amount of air for combustion and delivers it to the point of ignition, usually in the form of a spray.

The fuel oil is prepared for combustion either by vaporization or by atomization. These two methods of fuel oil preparation are used in the three basic types of oil burners employed in commercial, industrial, and residential heating. The following are the three basic types of oil burners:

1. Gun-type (atomizing) oil burners.
2. Vaporizing (pot-type) oil burners.
3. Rotary oil burners.

Gun-type atomizing oil burners are available as either low-pressure or high-pressure types (see Figures 1-1, 1-2, and 1-3). Both are used in residential heating applications with the latter being by far the more popular of the two. The remainder of this chapter is devoted to a description of the gun-type high-pressure atomizing oil burners used in residential and light commercial oil heating systems.

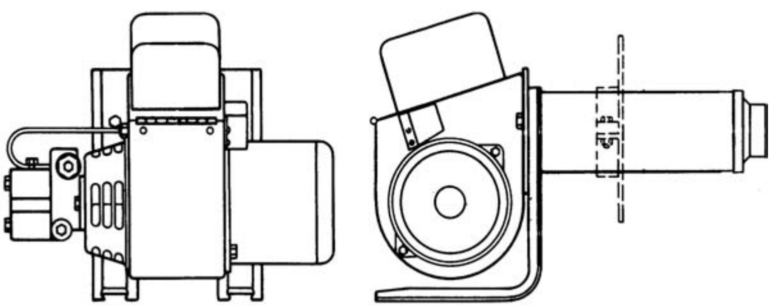

Figure 1-1 Basic shape of a gun-type oil burner.
(Courtesy Stewart-Warner Corp.)

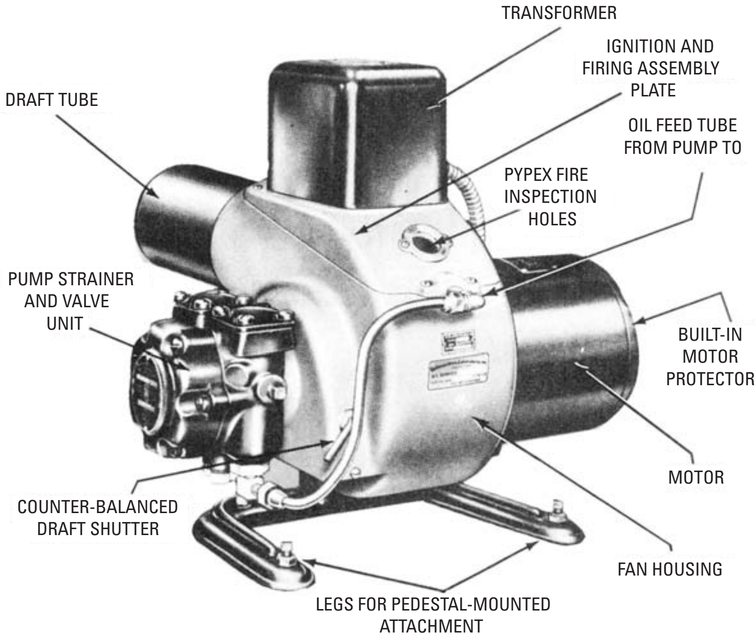

Figure 1-2 Principal components of an S.T. Johnson gun-type oil burner. *(Courtesy S.T. Johnson Company)*

The advantage of the vaporizing (pot-type) oil burner is its low operating cost. It is the least expensive to use, but it has limited heating applications. It is currently used only in small structures located in milder climates. Vaporizing burners can be divided into the three following types:

1. Natural-draft pot burners.
2. Forced-draft pot burners.
3. Sleeve burners.

Rotary oil burners are commonly used in the heating systems of commercial or industrial buildings, although they can and have been used for residential heating applications (see Figures 1-4 and 1-5). The following types of rotary oil burners are available for heating purposes:

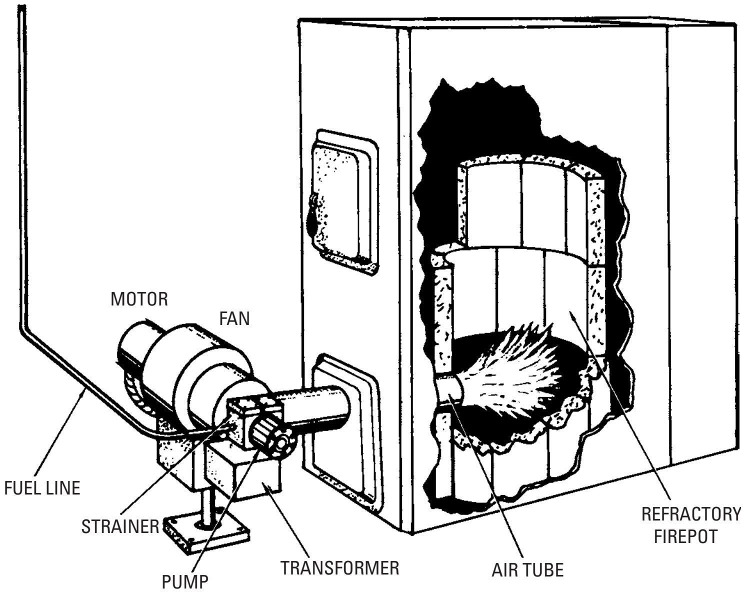

Figure 1-3 Gun-type oil burner firing into furnace combustion chamber. *(Courtesy U.S. Department of Agriculture)*

- Vertical rotary burners
- Horizontal rotary burners
- Wall-flame rotary burners

Gun-Type Oil Burners

Gun-type, high-pressure atomizing oil burners are sometimes called *sprayers* or *atomizing burners* because they spray the fuel oil instead of vaporizing it. They are also referred to as *gun* or *pressure* oil burners because the oil is forced under pressure through a special gun-like atomizing nozzle. The liquid fuel is broken up into minute liquid particles or globules to form the spray.

Construction Details

The principal components and parts of a gun-type, high-pressure atomizing oil burner used in residential and light commercial oil heating systems are illustrated in Figures 1-6 and 1-7. The

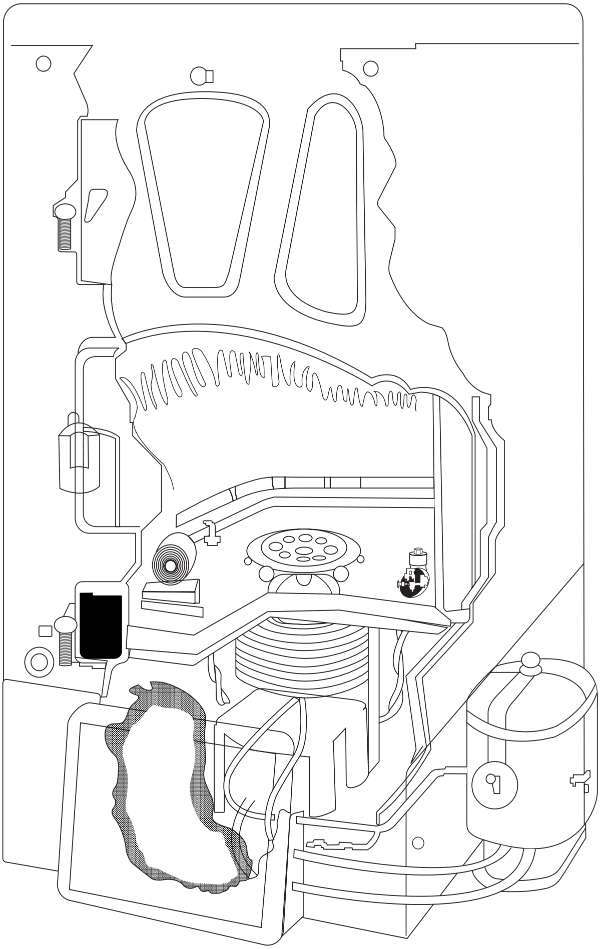

Figure 1-4 Cutaway view of a vertical rotary burner of the vaporizing or wall-flame type. *(Courtesy Integrated Publishing)*

construction details of gun-type oil burners will vary somewhat in different makes and models, but the overall design of these burners is now nearly standardized. The components and parts of a typical gun-type oil burner can be divided into the following categories:

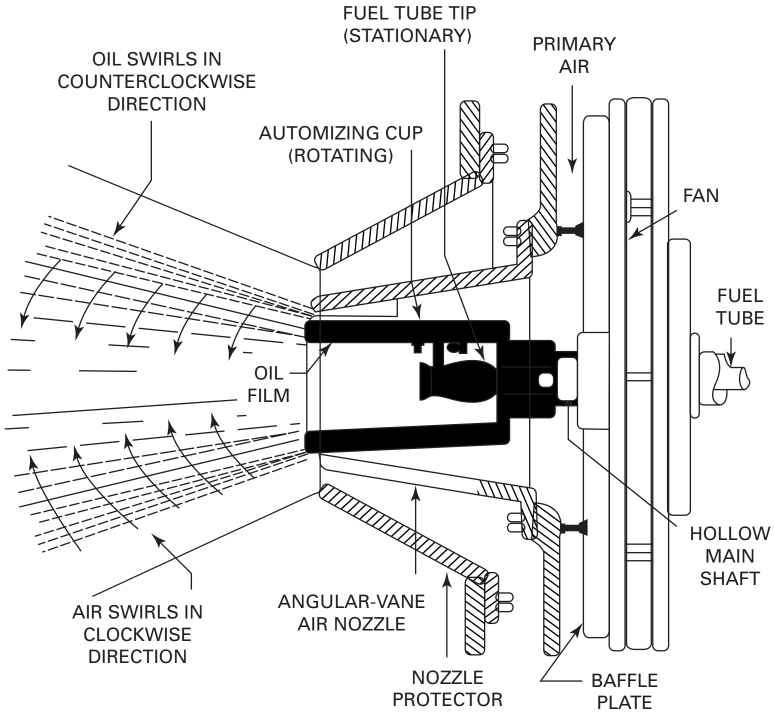

Figure 1-5 Horizontal rotary burner. *(Courtesy Integrated Publishing)*

1. Burner control.
2. Primary safety control.
3. Gun assembly.
4. Ignition transformer.
5. Burner motor and coupling.
6. Fuel pump.
7. Combustion air blower.

Burner Control

The *burner control* is the operational control center of the burner. As shown in Figures 1-6 and 1-7, it is located on the right side of the burner assembly directly above the combustion air blower housing. It operates in conjunction with the primary control and a bimetallic

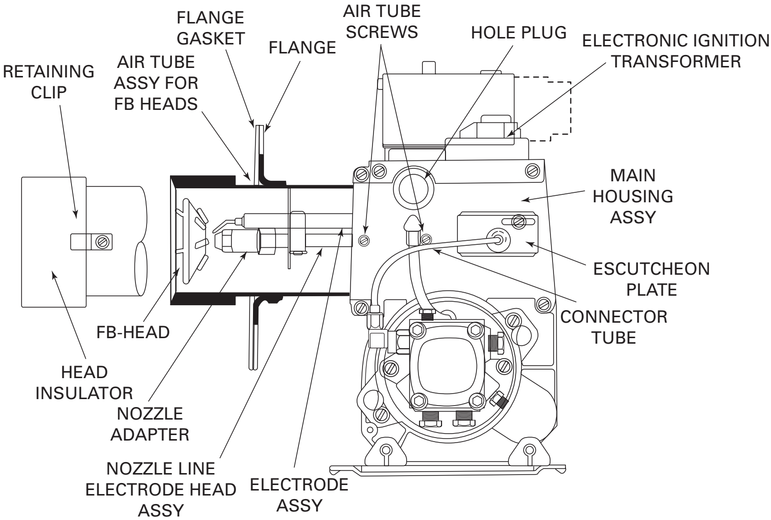

Figure 1-6 Typical gun-type oil burner (side view).
(Courtesy Lennox Industries Inc.)

temperature sensor. When the room thermostat calls for heat and the ignition cycle begins, the burner control will start the burner *only* when the cad cell detects (proves) a flame. The burner control shuts off the burner if the cad cell fails to prove the flame or if the bimetallic sensor detects a temperature too high for safe operation.

Primary Safety Control

The *primary safety control* is an automatic safety device designed to stop the flow of fuel oil at the burner should ignition or flame failure occur. Modern oil-fired furnaces and boilers use a cad cell as the primary control to prove the flame; older ones were equipped with a stack detector primary control. The former is mounted inside the burner behind the access door (see Figure 1-8), and the latter is located in the stack.

Gun Assembly

The oil burner gun assembly consists of a burner nozzle, the electrodes, and a tube connecting the electrodes to the fuel pump (see Figure 1-9). The burner nozzle changes the fuel oil into a form that can be burned in the combustion chamber. It accomplishes this by forcing the oil under pressure through a small hole at the end of the nozzle. The atomized fuel oil is ignited by spark from the electrodes.

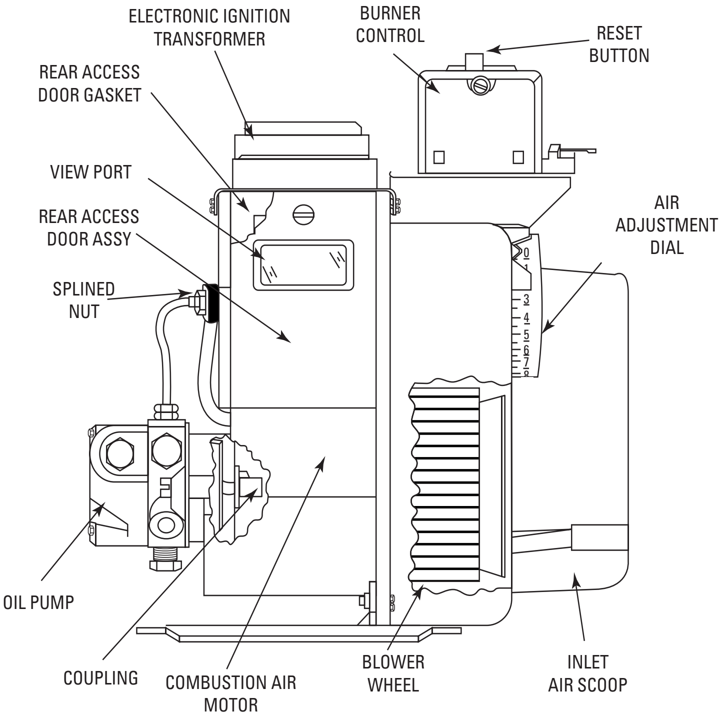

Figure 1-7 Typical gun-type oil burner (front view).
(Courtesy Lennox Industries Inc.)

Ignition Transformer

A step-up ignition transformer located on top of the burner assembly produces the voltage used by the electrodes to ignite the fuel oil. This type of transformer is designed to increase the voltage of a high-voltage (110 VAC) circuit to the ultrahigh 14,000 volts required to ignite the fuel oil.

Burner Motor and Coupling

As shown in Figure 1-5, the burner motor is located on the right side of the oil burner assembly. The drive shaft of the burner motor is connected to both the fuel pump and the combustion air blower by a coupling that functions as the drive shaft for both of these units. A burner motor is also sometimes called an *oil pump motor* or a *pump motor* because it is connected to and drives the fuel (oil) pump.

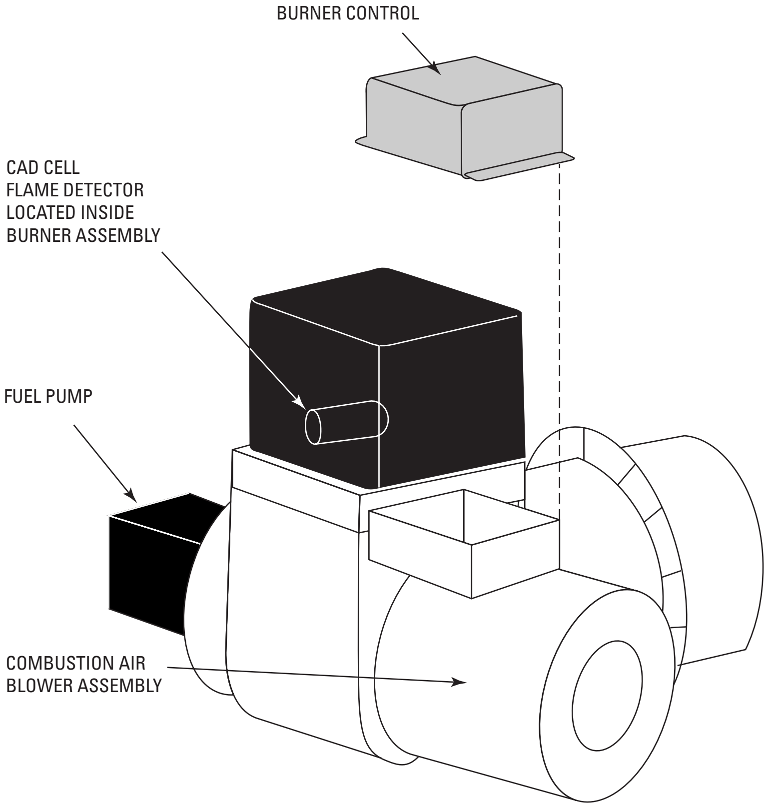

Figure 1-8 Locations of burner control and cadmium cell primary safety control.

Fuel Pump

The fuel pump (also called an *oil pump* or a *fuel unit*) is used to draw fuel oil from the storage tank and deliver it under high pressure (100 to 140 psi) to the nozzle assembly (see Figure 1-11). It is driven by the burner motor and coupling and is located on the left side of the oil burner.

Combustion Air Blower

The combustion air blower is also driven by the burner motor and coupling. It is located between the burner motor and the fuel pump. Its function is to introduce the required amount of air for the

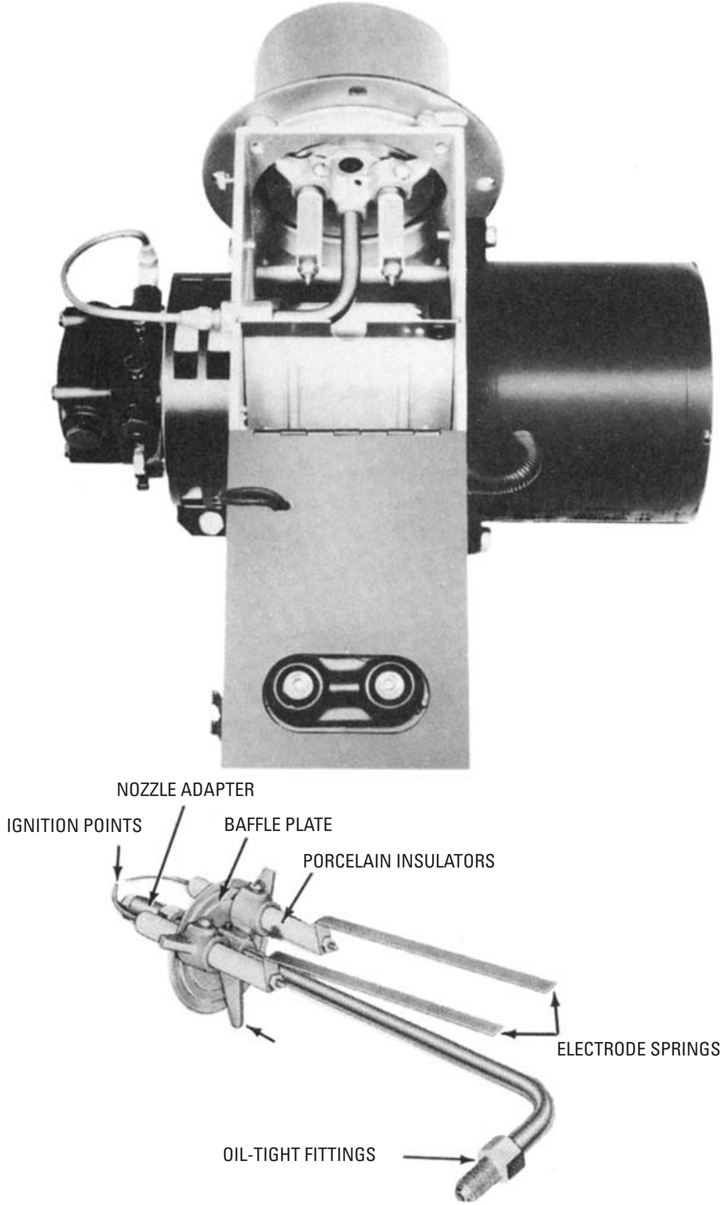

Figure 1-9 Oil burner with transformer removed revealing the gun assembly. *(Courtesy Wayne Home Equipment Co., Inc.)*

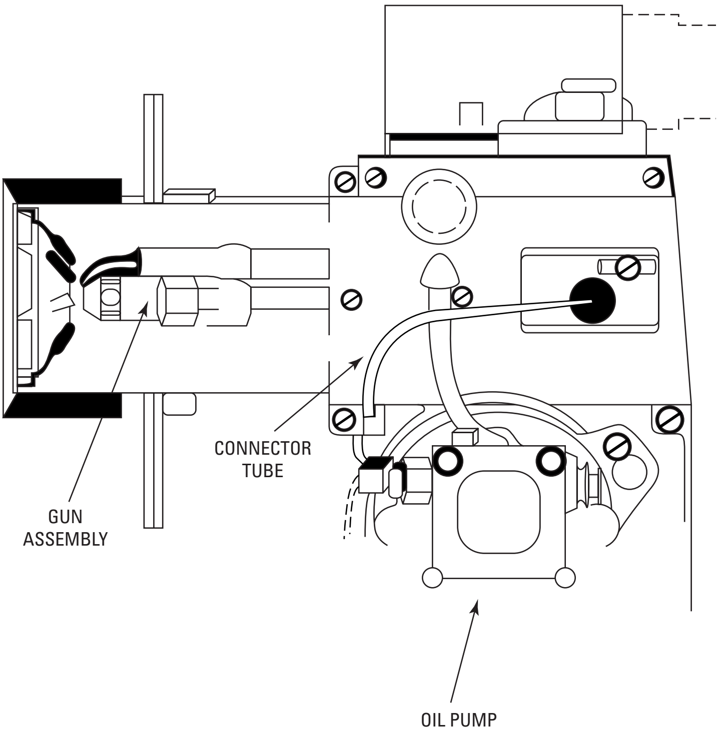

Figure 1-10 Gun assembly details. *(Courtesy Lennox Industries Inc.)*

combustion process. The amount of air can be manually adjusted by an air adjustment gauge located between the blower wheel and the inlet air scoop (see Figure 1-7). Depending on the oil burner manufacturer, a combustion air blower is also sometimes called a *blower wheel*, a *burner motor fan*, or an *induction blower*. Do not confuse the combustion air blower with the furnace indoor blower. The former delivers air to the oil burner for combustion. The latter delivers the heated air to the rooms and spaces inside the structure.

Operating Principles

The operation of a gun-type, high-pressure atomizing oil burner can be traced in Figure 1-12. The fuel oil is drawn through a strainer from the supply tank by the fuel pump and is forced under pressure past the pressure relief cutoff valve via the oil line where it eventually passes through the fine mesh strainer and into the nozzle. The amount of pressure required to pump the fuel oil through

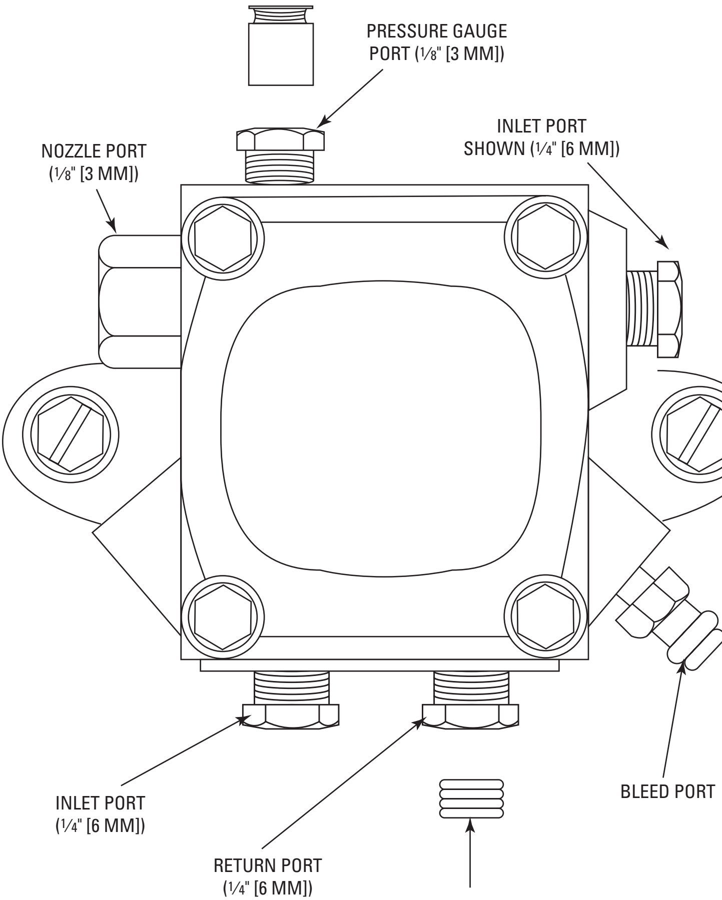

Figure 1-11 Typical fuel pump. *(Courtesy Lennox Industries Inc.)*

the line depends on the size and capacity of the oil burner and the purpose for which it is used. For example, residential oil burners require 80 to 125 psi, whereas commercial and industrial oil burners operate on 100 to 300 psi.

As the fuel oil passes through the nozzle, it is broken up and sprayed in a very fine mist. The air supply is drawn in through the inlet air scoop opening (see Figure 1-5) and forced through the draft tube portion of the casing by the combustion air blower. This air mixes with the oil spray after passing through a set of vanes,

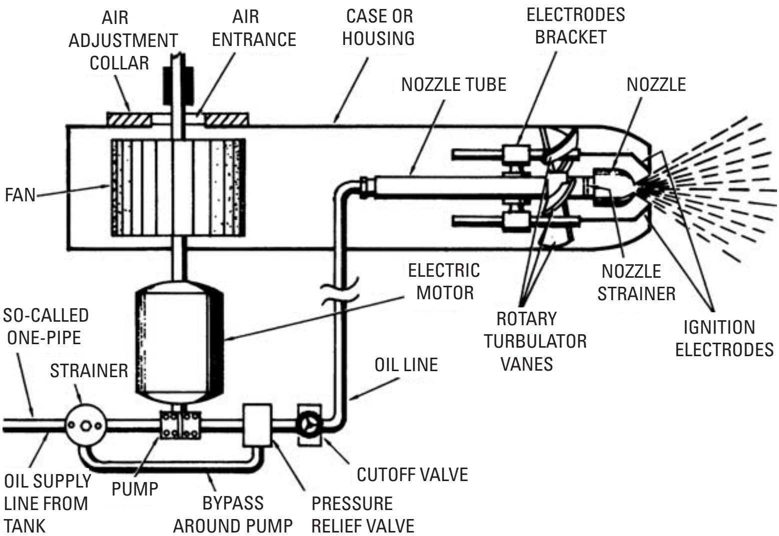

Figure 1-12 Schematic of a gun-type oil burner.

called a *turbulator.* The turbulator gives a twisting motion to the air stream just before it strikes the oil spray, producing a more thorough mixture of the oil and air (see Figure 1-13).

Ignition of the oil spray is provided by a transformer that changes the house lighting current and feeds it to the electrodes to provide a spark at the beginning of each operating period.

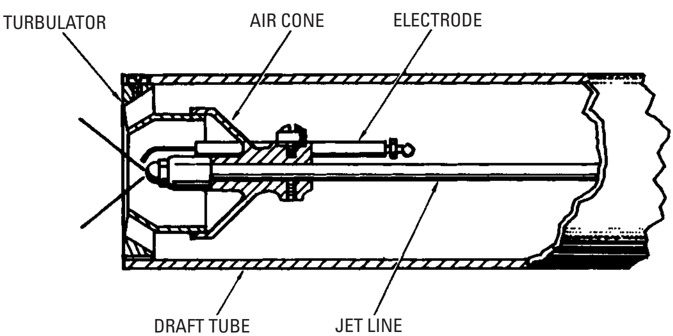

Figure 1-13 Details of draft tube illustrating the location of the turbulator, air cone, and electrode.

The starting cycle of the oil burner is initiated by the closing of the motor circuit. When the motor circuit is closed (automatically by room temperature control), the motor starts turning the fan and the pump. At the same time, the ignition transformer produces a spark at the electrodes ready to light the oil and air mixture.

The action of the pump draws the fuel oil from the tank through the strainer on the fuel line. Its flow is controlled by an oil cutoff valve, which prevents oil passing to the nozzle unless the pressure is high enough to spray the oil (approximately 60 lbs of pressure). Because the pump in the oil burner pumps oil much faster than it can be discharged through the nozzle at that pressure (i.e., 60 lbs of pressure), the oil pressure continues to rise very fast between the pump and the nozzle. When the pressure begins to rise above the normal operating pressure (100 lbs), a pressure relief valve opens and allows the excess oil to flow through the bypass line to the inlet, as in the so-called one-pipe system, or to flow through a second or return line to the supply tank. The pressure relief valve in either system maintains the oil at the correct operating pressure.

When the oil burner is turned off (i.e., when the burner motor stops), the oil pressure quickly drops below the operating pressure, and a pressure relief valve closes. The flame continues until the pressure drops below the setting of the cutoff valve.

The cutoff and pressure relief (regulating) valves may be either two separate units or combined into one unit. Figure 1-14 shows the essentials of the two-unit arrangement. These are, as shown, simply elementary schematics designed to illustrate basic operating principles. The cutoff needle valve is shown with a spring inside the bellows, and the pressure relief (mushroom) valve is shown with exposed spring. In the cutoff valve arrangement, the spring acts against oil pressure on the head of the bellows (tending to collapse it); in the pressure relief valve, the spring acts against the oil pressure, which acts on the lower face of the mushroom valve (tending to open it).

When the pump starts and the pressure in the line rises to about 60 lbs (depending on the spring setting), this pressure acting on the head of the bellows overcomes the resistance of the spring, causing the cutoff valve to open. Since the pump supplies more oil than the nozzle can discharge, the pressure quickly rises to 100 lbs, overcoming the resistance of the relief valve spring and causing the valve to open. This allows excess oil to bypass or return to the tank.

The relief valve will open high enough to maintain the working pressure constant at 100 lbs. When the oil burner is turned off, the oil pressure quickly drops, and the pressure relief valve closes.

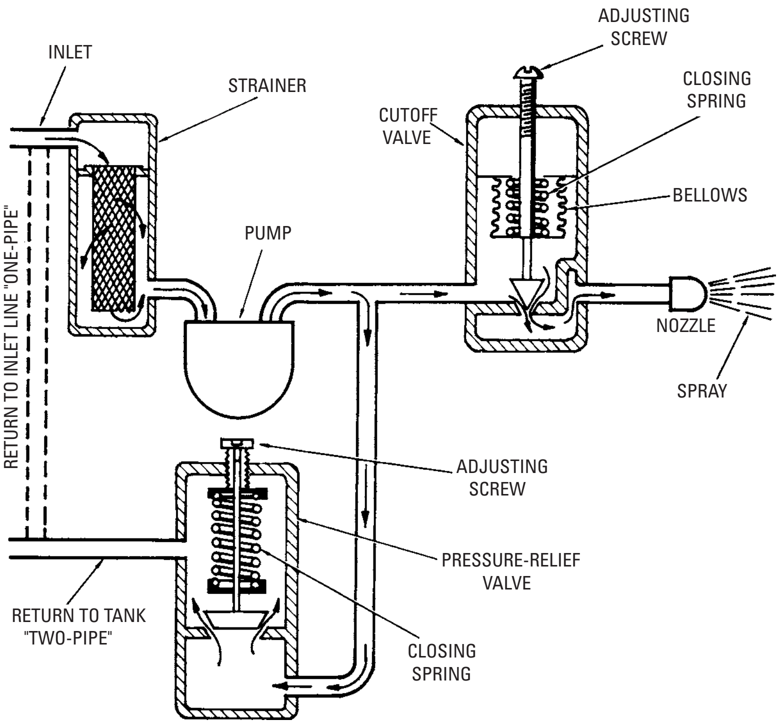

Figure 1-14 Schematic sectional view of separate unit cutoff valve and pressure relief valve showing strainer, pump, and piping.

However, oil will continue to discharge from the nozzle until the pressure drops below the cutoff valve setting when the cutoff valve closes and stops the nozzle discharge.

A passage to the return line is provided by a small slot cut in the seat of the mushroom valve. This causes any remaining pressure trapped in the line by the closing of the cutoff valve to be equalized.

Frequently the cutoff valve and pressure relief valve are combined in a compact cylindrical casing (see Figure 1-15). Here the two valves are attached to a common stem with a flange, which comes in contact with a stop when moved upward by the pressure of the valve actuating the spring.

The position of the stop limits the valve movements to proper maximum lift. A piston, free to move in the cylindrical casing, has an opening in its head that forms the valve seat for the pressure relief