

**Audel**

**HVAC Fundamentals**  
**Volume 2**

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

**All New 4<sup>th</sup> Edition**

**James E. Brumbaugh**



Wiley Publishing, Inc.

Vice President and Executive Group Publisher: Richard Swadley  
Vice President and Executive Publisher: Robert Ipsen  
Vice President and Publisher: Joseph B. Wikert  
Executive Editor: Carol A. Long  
Acquisitions Editor: Katie Feltman  
Editorial Manager: Kathryn A. Malm  
Senior Production Manager: Fred Bernardi  
Development Editor: Kenyon Brown  
Production Editor: Vincent Kunkemueller  
Text Design & Composition: TechBooks

Copyright © 2004 by Wiley Publishing, Inc., Indianapolis, Indiana. All rights reserved.

Published simultaneously in Canada

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning, or otherwise, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, (978) 750-8400, fax (978) 646-8700. Requests to the Publisher for permission should be addressed to the Legal Department, Wiley Publishing, Inc., 10475 Crosspoint Blvd., Indianapolis, IN 46256, (317) 572-3447, fax (317) 572-4447, E-mail: permcoordinator@wiley.com.

**Limit of Liability/Disclaimer of Warranty:** The publisher and the author make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation warranties of fitness for a particular purpose. No warranty may be created or extended by sales or promotional materials. The advice and strategies contained herein may not be suitable for every situation. This work is sold with the understanding that the publisher is not engaged in rendering legal, accounting, or other professional services. If professional assistance is required, the services of a competent professional person should be sought. Neither the publisher nor the author shall be liable for damages arising herefrom. The fact that an organization or Web site is referred to in this work as a citation and/or a potential source of further information does not mean that the author or the publisher endorses the information the organization or Web site may provide or recommendations it may make. Further, readers should be aware that Internet Web sites listed in this work may have changed or disappeared between when this work was written and when it is read.

For general information on our other products and services, please contact our Customer Care Department within the United States at (800) 762-2974, outside the United States at (317) 572-3993 or fax (317) 572-4002.

Trademarks: Wiley, the Wiley Publishing logo, and Audel are trademarks or registered trademarks of John Wiley & Sons, Inc., and/or its affiliates. All other trademarks are the property of their respective owners. Wiley Publishing, Inc., is not associated with any product or vendor mentioned in this book.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

**Library of Congress Cataloging-in-Publication Data**

eISBN: 0-7645-7436-1

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

For Laura, my friend, my daughter.



# Contents

---

Introduction	xv	
About the Author	xvi	
Chapter 1	Oil Burners	1
	Gun-Type Oil Burners	3
	Construction Details	3
	Operating Principles	10
	Flame-Retention Head Burners	16
	High-Static Oil Burners	16
	Rotary Oil Burners	16
	Vaporizing (Pot-Type) Oil Burners	18
	Combination Oil and Gas Burners	18
	Fuel Pump	19
	Single-Stage Fuel Pump	21
	Two-Stage Pump	25
	Fuel Pump Capacity	26
	Fuel Pump Service and Maintenance	26
	Priming Fuel Pumps	29
	Adjusting Fuel Pump Pressure	29
	Troubleshooting Fuel Pumps	31
	Fuel Supply Tank and Line	32
	Oil Burner Nozzles	32
	Electrodes	36
	Troubleshooting Electrodes	37
	Servicing Electrodes	37
	Oil Burner Air System	37
	Primary Safety Control Service	40
	Installing an Oil Burner	40
	Starting an Oil Burner	42
	Air Delivery and Blower Adjustment	43
	Combustion Testing and Adjustments	43
	Troubleshooting Oil Burners	48

<b>Chapter 2</b>	<b>Gas Burners</b>	<b>57</b>
	Operating Principles	57
	Electrical Circuits	61
	Automatic Controls	61
	Types of Gas Burners	63
	Integral-Type Gas Burners	65
	Gas Conversion Burners	66
	Gas Conversion Burner Combustion Chambers	67
	Gas Piping for Conversion Burners	68
	Venting and Ventilation	71
	Safety Precautions	72
	Troubleshooting Gas Burners	73
<b>Chapter 3</b>	<b>Coal Firing Methods</b>	<b>77</b>
	Coal-Firing Draft Requirements	77
	Firing Anthracite Coal	78
	Firing Bituminous Coal	80
	Firing Semibituminous Coal	81
	Stoker Firing	81
	Stoker Construction	84
	Stoker Automatic Controls	86
	Stoker Operating Instructions	90
	Coal Selection	91
	Starting the Fire	91
	Natural Stack Draft	91
	Manual Air Adjustment	92
	Automatic Air Control	92
	Changing Coal Feeds	92
	Motor Overload Protection	92
	Transmission Overload Protection	93
	Removal of Obstruction	93
	Lubrication	93
	Summer Service	93
	How to Remove Clinkers	94
	How to Adjust Coal Feed	94

	How to Adjust Air Supply	94
	Troubleshooting Coal Stokers	94
<b>Chapter 4</b>	<b>Thermostats and Humidistats</b>	<b>99</b>
	Automatic Control Systems	99
	Temperature Control Circuits	100
	Thermostats	100
	Thermostat Components	105
	Thermostat Terminal Identification	109
	Thermostat Anticipators	109
	Types of Thermostats	119
	Room Thermostats	119
	Programmable Thermostats	125
	Insertion Thermostats	125
	Immersion Thermostats	126
	Cylinder Thermostats	127
	Boiler Thermostats	129
	Remote-Bulb Thermostats	129
	Proportional Thermostats	132
	Outdoor Thermostats	132
	Troubleshooting Thermostats	134
	Humidistats	134
	Location of Room Humidistats	140
	Troubleshooting Humidistats	142
<b>Chapter 5</b>	<b>Gas and Oil Controls</b>	<b>145</b>
	Gas Controls	145
	Gas Control Circuits	146
	Gas Burner Primary Control	146
	Servicing a Gas Burner Primary Control	151
	Gas Valves	153
	Solenoid Gas Valves	153
	Solenoid Coils	158
	Direct-Acting Heat Motor Valves	163
	Diaphragm Valves	164
	Pressure Regulators	166
	Pressure Switches	170

Automatic Pilot Safety Valve	174
Thermopilot Valves	178
Thermocouples	181
Troubleshooting Thermocouples	183
Thermopiles (Pilot Generators)	184
Pilot-Operated Diaphragm Valves	185
Combination Gas Valves	187
Standing Pilot Combination Gas Valves	187
Continuous Pilot Dual Automatic Gas Valve	191
Universal Electronic Ignition Combination Gas Valve	194
Pilot Burners	194
Installing a Pilot Burner	198
Replacing the Pilot Burner Orifice	200
Lighting the Pilot	201
Pilot Flame Adjustment	202
Main Burner Ignition	202
Pilot-Pressure Switch	203
Electronic Ignition Modules	203
Intermittent Pilot Ignition Module	204
Direct-Spark Ignition Module	207
Hot-Surface Ignition Module	208
Igniters	211
Flame Sensors	214
Mercury Flame Sensors	216
Oil Controls	217
Oil Valves	217
Oil Burner Primary Control	219
Cadmium Cell Primary Controls	220
Stack Detector Primary Control	223
Combination Primary Control and Aquastat	227
Troubleshooting the Oil Burner Primary Control	231



<b>Chapter 6</b>	<b>Other Automatic Controls</b>	<b>233</b>
	Fan Controls	233
	Fan Control	233
	Air Switch	236
	Fan Relays	237
	Fan Center	239
	Fan Manager	241
	Fan Timer Switch	241
	Fan Safety Cutoff Switch	242
	Limit Controls	244
	Limit Control	244
	Secondary High-Limit Switch	248
	Combination Fan and Limit Control	251
	Switching Relays	256
	Impedance Relays	259
	Heating Relays/Time-Delay Relays	261
	Potential Relay	263
	Pressure Switches	265
	Sail Switches	266
	Other Switches and Relays	268
	Sequence Controllers	269
	Contactors	275
	Troubleshooting Contactors	277
	Cleaning Contactors	280
	Replacing Contactors	280
	Motor Starter	281
	Overload Relay Heater	281
	Inherent Protector	282
	Pilot Duty Motor Protector	283
	Capacitors	284
	Troubleshooting Capacitors	287
	Replacing Capacitors	287
	High-Pressure Cutout Switch	288
	Low-Pressure Cutout Switch	289
	Transformers	290
	Sizing Transformers	291

	Installing Transformers	291
	Control Panels	293
<b>Chapter 7</b>	<b>Ducts and Duct Systems</b>	<b>295</b>
	Codes and Standards	295
	Types of Duct Systems	295
	Perimeter Duct Systems	296
	Extended Plenum Systems	297
	Crawl-Space Plenum Systems	297
	Duct Materials	298
	Duct System Components	299
	Supply Air Registers, Grilles, and Diffusers	301
	Return Air and Exhaust Air Inlets	302
	Duct Run Fittings	303
	Air Supply and Venting	305
	Duct Dampers	305
	Damper Motors and Actuators	313
	Installing Damper Motors	316
	Troubleshooting Damper Motors	320
	Blowers (or Fans) for Duct Systems	321
	Designing a Duct System	322
	Duct System Calculations	323
	Duct Heat Loss and Gain	324
	Air Leakage	325
	Duct Insulation	325
	Equal Friction Method	326
	Balancing an Air Distribution System	331
	Duct Maintenance	331
	Roof Plenum Units	332
	Mobile Home Duct Systems	333
	Proprietary Air Distribution Systems	336
	Duct Furnaces	338
	Electric Duct Heaters	347

<b>Chapter 8</b>	<b>Pipes, Pipe Fittings, and Piping Details</b>	<b>355</b>
	Types of Pipe Materials	355
	Wrought-Iron Pipe	356
	Wrought-Steel Pipe	363
	Galvanized Pipe	363
	Copper and Brass Pipes and Tubing	363
	Plastic Tubing	367
	Synthetic Rubber Hose	369
	Composite Tubing	369
	Pipe Fittings	369
	Classification of Pipe Fittings	370
	Extension or Joining Fittings	370
	Reducing or Enlarging Fittings	378
	Directional Fittings	380
	Branching Fittings	380
	Shutoff or Closing Fittings	382
	Union or Makeup Fittings	382
	Flanges	382
	Pipe Expansion	382
	Valves	384
	Pipe Threads	384
	Pipe Sizing	384
	Sizing Steam Pipes	385
	Sizing Hot-Water (Hydronic)	
	Pipes/Tubing	393
	Pipe Fitting Measurements	396
	Calculating Offsets	397
	First Method	400
	Second Method	401
	Third Method	401
	Fourth Method	403
	Pipe Supports	403
	Joint Compound	403
	Pipe Fitting Wrenches	406
	Pipe Vise	409

Installation Methods	410
Pipe Cutting	410
Pipe Threading	412
Pipe Reaming	414
Pipe Cleaning	414
Pipe Tapping	414
Pipe Bending	415
Assembling and MakeUp	415
Nonferrous Pipes, Tubing, and Fittings	420
Soldering Pipe	420
Brazing Pipes	424
Braze Welding Pipe	425
Welding Pipe	425
Gas Piping	429
Insulating Pipes	429
Piping Details	430
Connecting Risers to Mains	431
Connections to Radiators or Convectors	431
Lift Fittings	431
Drips	432
Dirt Pockets	434
Siphons	434
Hartford Connections	434
Making Up Coils	434
Relieving Pipe Stress	436
Swivels and Offsets	439
Eliminating Water Pockets	440
Pressure Tests	444
<b>Chapter 9</b>	
<b>Valves and Valve Installation</b>	<b>445</b>
Valve Components and Terminology	445
Valve Materials	451
Globe and Angle Valves	454
Gate Valves	456
Check Valves	458

Stop Valves	463
Butterfly Valves	465
Two-Way Valves	467
Three-Way Valves	469
Y Valves	469
Valve Selection	469
Troubleshooting Valves	472
Valve Stuffing-Box Leakage	474
Valve Seat Leakage	474
Damaged Valve Stems	475
Automatic Valves and Valve Operators	475
Valve Pipe Connections	487
Valve Installing Pointers	489
Soldering, Brazing, and Welding Valves to Pipes	492
Soldering or Silver-Brazing Procedure	494
Butt-Welding Procedure	495
Socket-Welding Procedure	496
<b>Chapter 10 Steam and Hydronic Line Controls</b>	<b>497</b>
Steam and Hydronic System Pumps	497
Condensate Pumps	497
Circulators (Water-Circulating Pumps)	505
Circulator Selection	511
Steam Traps	518
Sizing Steam Traps	519
Steam Trap Maintenance	520
Automatic Heat-Up	520
Installing Steam Traps	522
Float Traps	523
Thermostatic Traps	524
Balanced-Pressure Thermostatic Steam Traps	525
Maintenance	526
Float and Thermostatic Traps	526
Thermodynamic Steam Traps	529

Bucket Traps	530
Flash Traps	534
Impulse Traps	534
Tilting Traps	536
Lifting Traps	537
Boiler Return Traps	537
Expansion Tanks	540
Closed Steel Expansion Tanks	541
Diaphragm Expansion Tanks	543
Sizing Expansion Tanks	543
Troubleshooting Expansion Tanks	544
Air Eliminators	545
Pipeline Valves and Controls	547
Temperature Regulators	548
Electric Control Valves (Regulators)	548
Water-Tempering Valves	550
Hot-Water Heating Control	554
Flow Control Valve	558
Electric Zone Valve	559
Balancing Valves, Valve Adapters, and Filters	561
Manifolds	564
Pipeline Strainers	565
<b>Appendix A Professional &amp; Trade Associations</b>	<b>567</b>
<b>Appendix B Manufacturers</b>	<b>579</b>
<b>Appendix C Data Tables</b>	<b>591</b>
<b>Appendix D Conversion Tables</b>	<b>629</b>
<b>Index</b>	<b>639</b>

# 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).

Last, but certainly not least, I would like to thank Katie Feltman, Kathryn Malm, Carol Long, Ken Brown, and Vincent Kunkemueller, my editors at John Wiley & Sons, whose constant support and encouragement made this project possible.

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 I

## Oil Burners

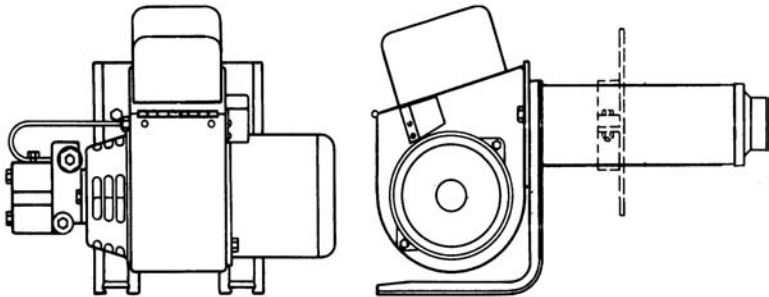
---

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.

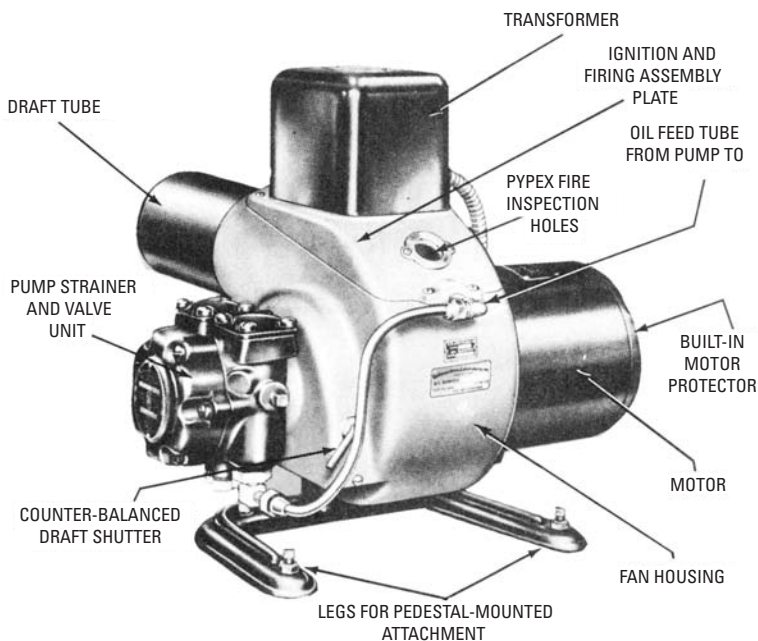
Gun-type atomizing oil burners are available as either low-pressure or high-pressure types (see Figures 1-1, 1-2, and 1-3). Both are used in residential heating applications with the latter being by far the more popular of the two. The remainder of this chapter is devoted to a description of the gun-type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

## 2 Chapter 1

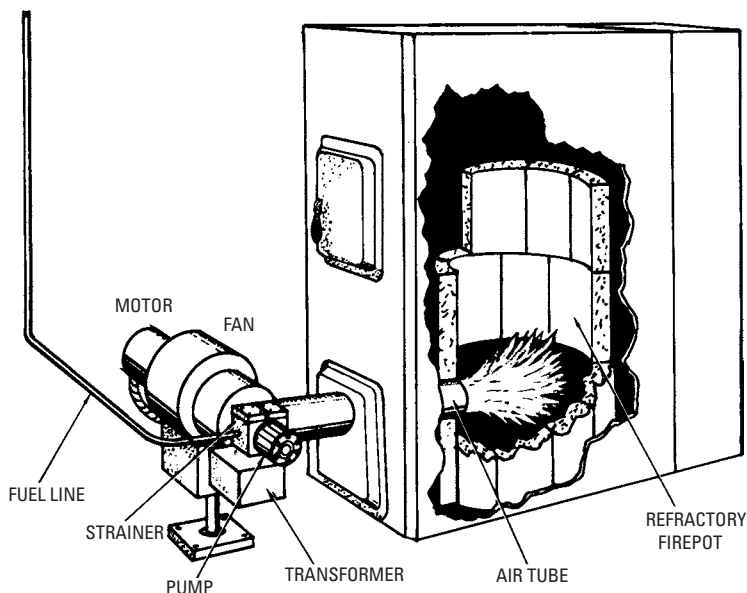


**Figure 1-2** Principal components of an S.T. Johnson gun-type oil burner. (Courtesy S.T. Johnson Company)

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)

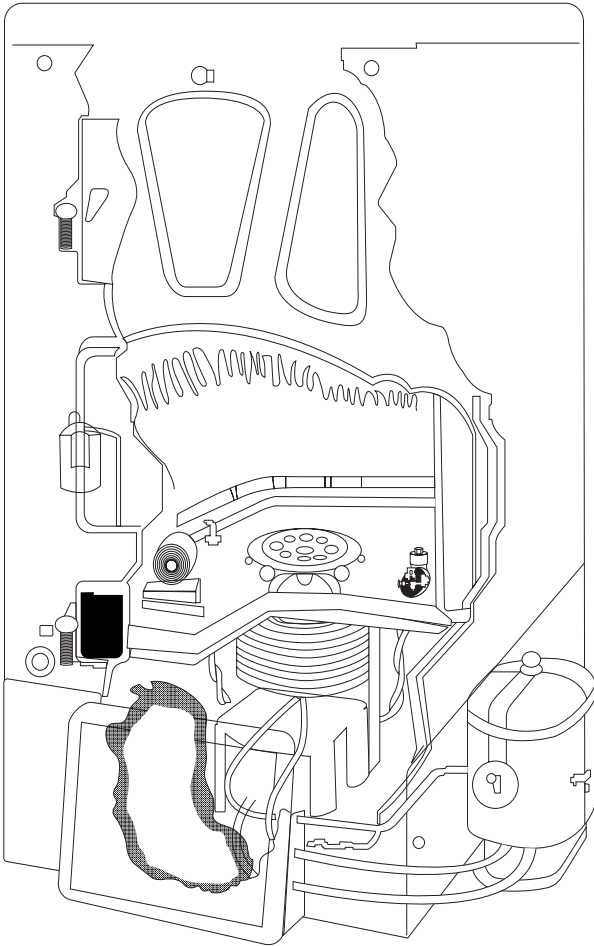
- Vertical rotary burners
- Horizontal rotary burners
- Wall-flame rotary burners

## 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.

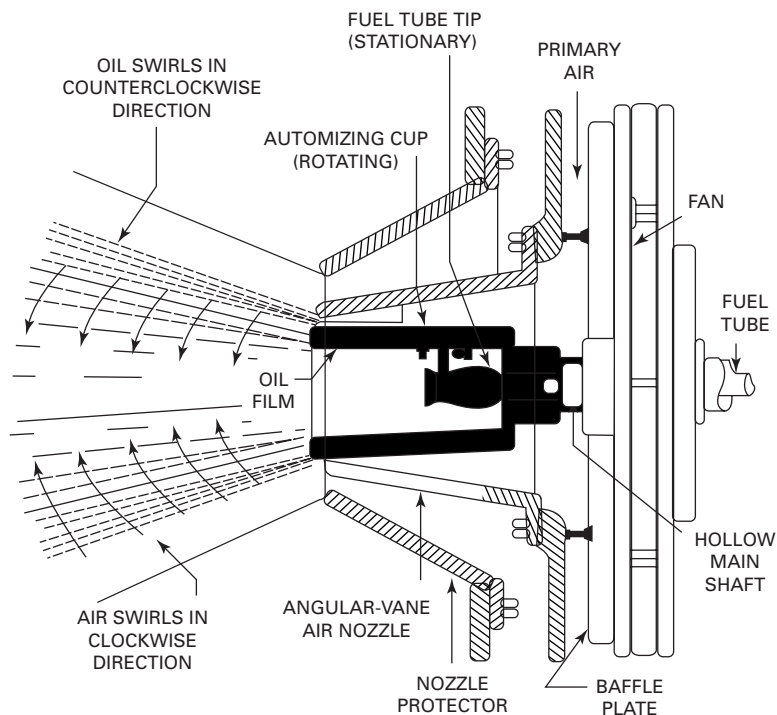
### Construction Details

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 I-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:



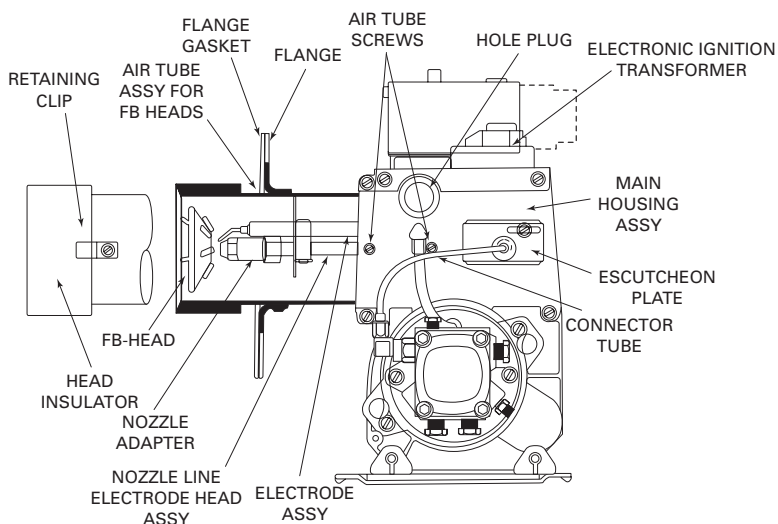
**Figure I-5** Horizontal rotary burner. (Courtesy Integrated Publishing)

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

## 6 Chapter I



**Figure 1-6** Typical gun-type oil burner (side view).

(Courtesy Lennox Industries Inc.)

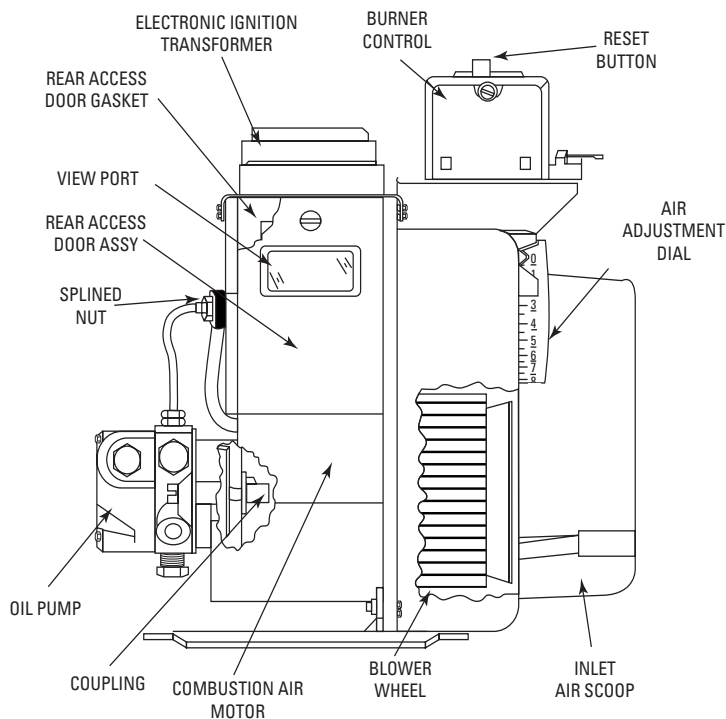
temperature sensor. When the room thermostat calls for heat and the ignition cycle begins, the burner control will start the burner *only* when the cad cell detects (proves) a flame. The burner control shuts off the burner if the cad cell fails to prove the flame or if the bimetallic sensor detects a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

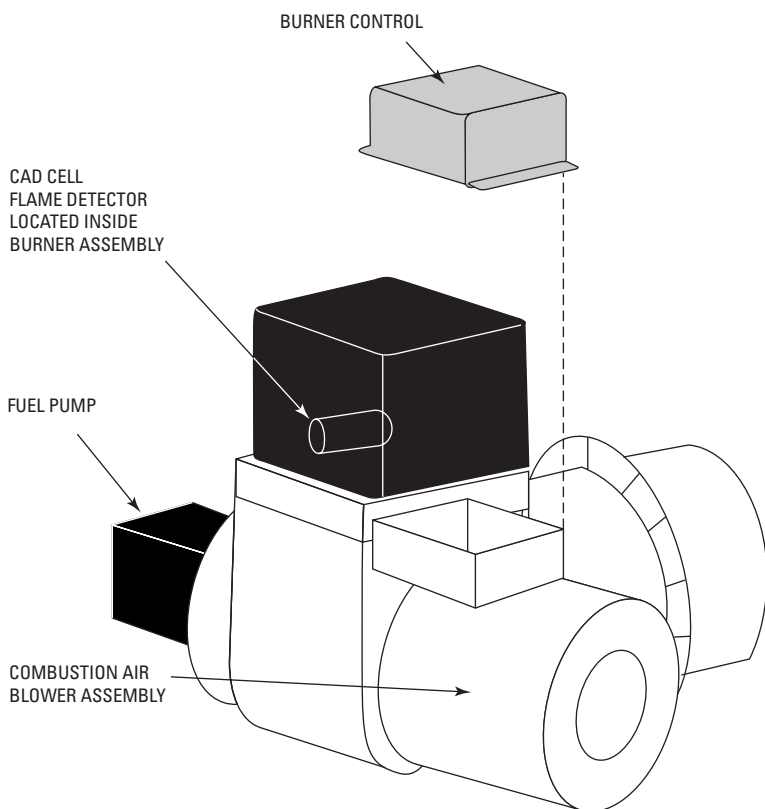
(Courtesy Lennox Industries Inc.)

### 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.

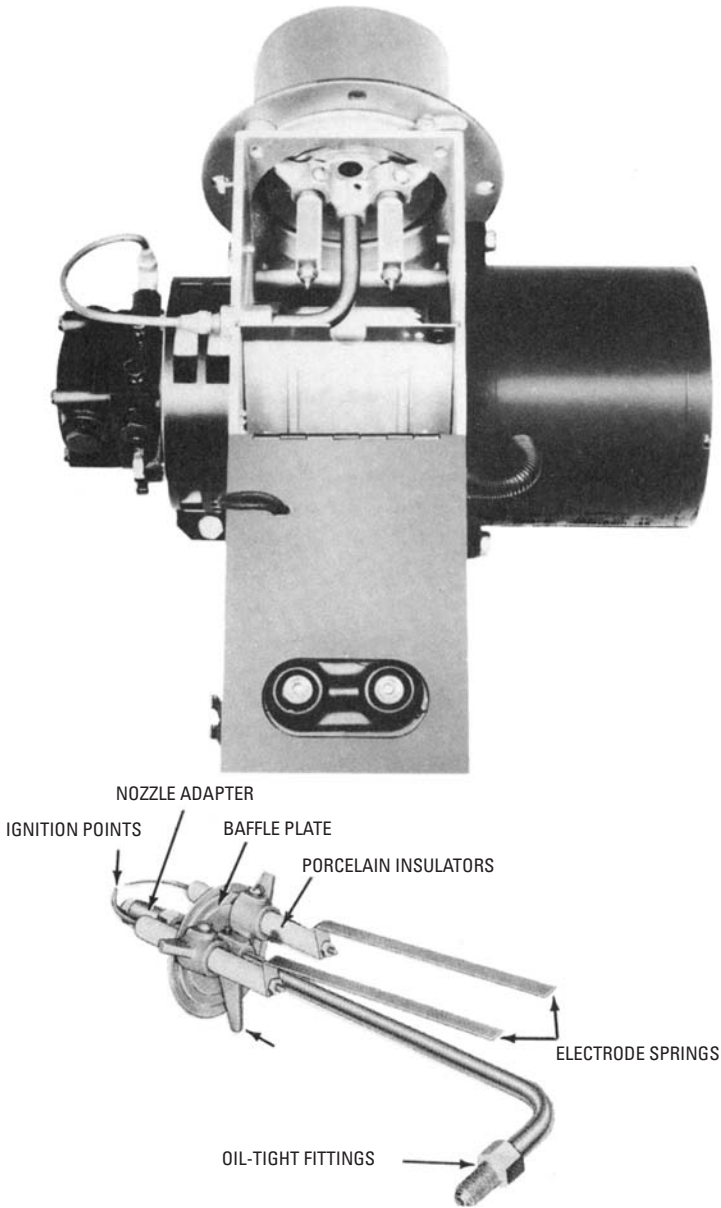
### Fuel Pump

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.

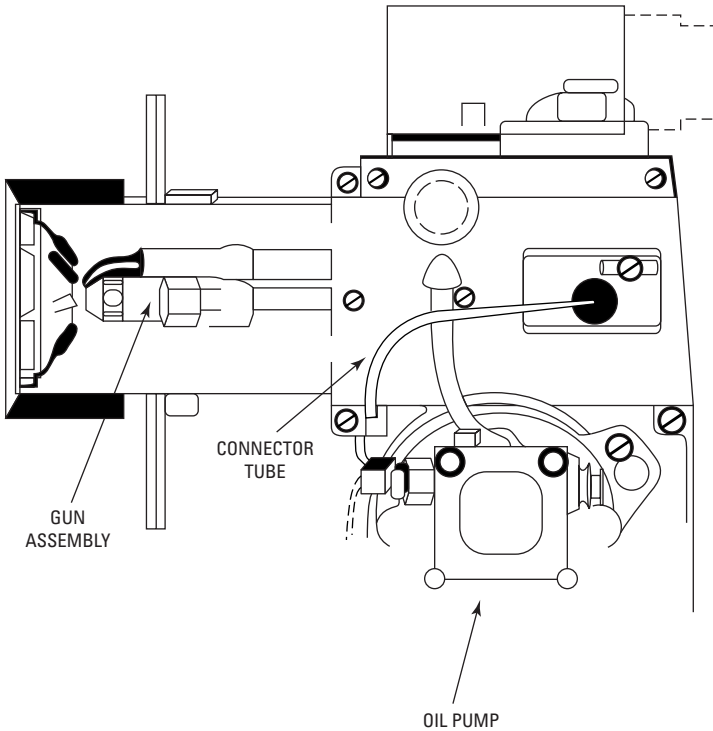
### Combustion Air Blower

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

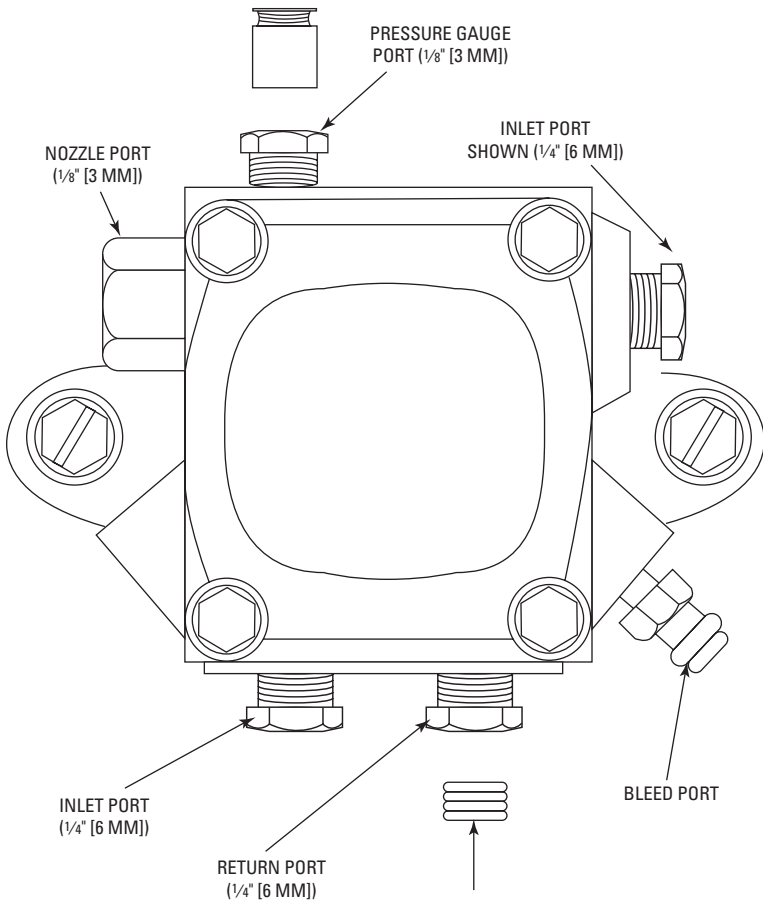


**Figure I-10** Gun assembly details. (Courtesy Lennox Industries Inc.)

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

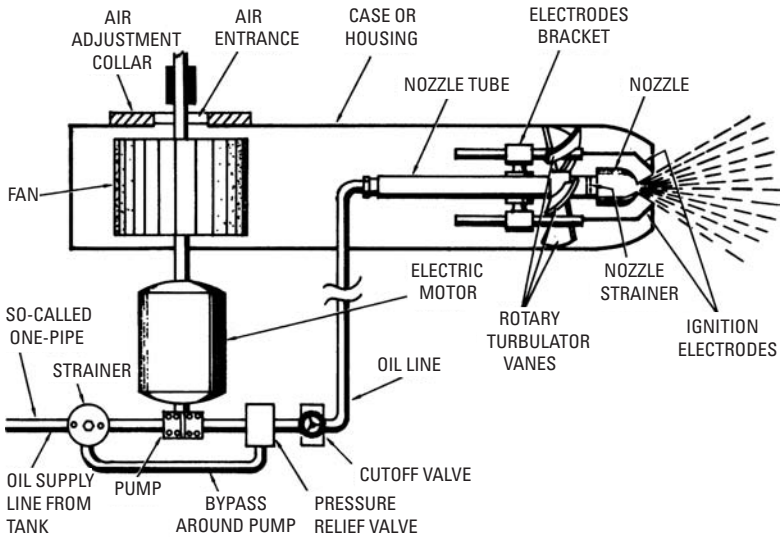


**Figure 1-11** Typical fuel pump. (Courtesy Lennox Industries Inc.)

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,

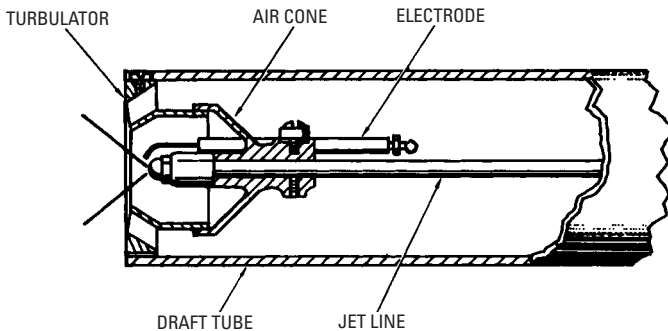
## 12 Chapter I



**Figure I-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 I-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.

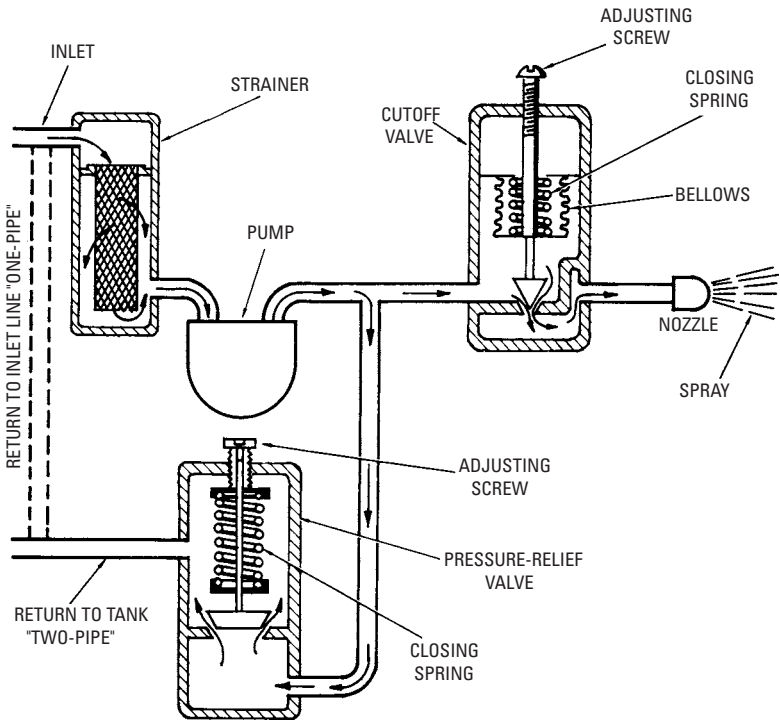
The action of the pump draws the fuel oil from the tank through the strainer on the fuel line. Its flow is controlled by an oil cutoff valve, which prevents oil passing to the nozzle unless the pressure is high enough to spray the oil (approximately 60 lbs of pressure). Because the pump in the oil burner 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 I-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