and may be such that the amount of excess air will decrease below allowable limits. A decrease in air supply while the oil delivery remains constant, or an increase in oil delivery while the air supply remains constant, can make the mixture of oil and air too rich for clean combustion. The more efficient the adjustment, the more critical it will be. The oil and air supply rates must remain constant.

The following factors may influence the oil delivery rate: (1) changes in oil viscosity due to temperature change or variations in grade of oil delivered; (2) erosion of atomizing nozzle; (3) fluctuations in bypass relief pressures; and (4) possible variations in methods of atomization. Any change due to partial stoppage of oil delivery will increase the proportion of excess air. This will result in less heat, reduced economy, and possibly a complete interruption of service.

The following factors may influence the air supply: (1) changes in combustion draft due to a variety of causes (i.e., changes in chimney draft because of weather changes, seasonal changes, back drafts, failure or inadequacy of automatic draft regulator, use of chimney for other purposes, possible stoppage of the chimney, and changes in draft resistance of boiler due to partial stoppage of the flues); and (2) changes in air inlet adjustments at the fan.

There should be no air leakage into the boiler or furnace setting. The overfire draft should be reduced as low as is consistent with the proper disposal of the products of combustion. When using mechanical draft burners with average conditions, the combustion chamber draft should not be allowed to exceed 0.02–0.05 in. water. An automatic draft regulator is necessary in order to maintain constant draft conditions which, in turn, improve efficiency of operation. The draft regulator should be adjusted in accordance with the manufacturer's instructions.

Even though a fan is generally used to supply the air for combustion, in most oil burners, the importance of a proper chimney should not be overlooked. The chimney should have sufficient height and size to insure a uniform draft within the limits given, if maximum efficiency throughout the heating season is to be maintained.

Measurement of the Efficiency of Combustion

Since efficient combustion is based upon a clean flame and definite proportions of oil and air employed, it is possible to determine the results by analyzing the combustion gases. It is customary to analyze only for carbon dioxide (CO_2) and to obtain the temperature of the stack gas. A showing of 10 to 12 percent indicates an excellent operation if the flame is clean. Many good installations operate with 8 to 10 percent CO_2.

Commercial Standard CS-75 requires that oil burners labeled as complying with the standard shall obtain smoke-free combustion at 10 percent CO_2. In all cases smokeless combustion is a requirement for oil burners.

Combustion Chamber Design

With burners requiring a refractory combustion chamber, the size and shape should be in accordance with the manufacturer's instructions. It is important that the chamber be as nearly airtight as is possible, except when the particular burner requires a secondary supply of air for combustion.

The atomizing burner is dependent upon the surrounding heated combustion chamber surfaces to reflect heat and help vaporize the oil. Unsatisfactory combustion may be due to inadequate atomization and mixing. A combustion chamber can only compensate for these things to a limited extent. If liquid fuel continually reaches some part of the firebrick surface, a carbon deposit will result. The combustion chamber should enclose a space having a shape similar to the flame, but large enough to avoid flame contact. The nearest approach in practice is to have the bottom of the combustion chamber flat, but far enough below the nozzle to avoid flame contact, the sides tapering from the air tube at the same angle as the nozzle spray, and the back wall rounded. A plan view of the combustion chamber resembles in shape the outline of the flame. This insures quick vaporization, rapid combustion and better mixing by eliminating dead spaces in the combustion chamber. An overhanging arch at the back of the fire pot is sometimes used to increase the flame travel and give more time for mixing and burning, and sometimes to prevent the gases from going too directly into the boiler flues. When good atomization and vigorous mixing are achieved by the burner, combustion chamber design becomes a less critical matter. Where secondary air is used, combustion chamber design is quite important. When installing some of the vertical rotary burners, the manufacturer's instructions must be followed carefully with regard to the hearth upon which successful performance depends in this type of burner.

Boiler Settings

Since the volume of space available for combustion is a determining factor in oil consumption, it is general practice in converting coal-fired boilers to remove grates and extend the combustion chamber downward to include or even exceed the ashpit volume; in new installations the boiler may be raised to make added volume available. Approximately 1 cu ft of combustion volume should be provided for every developed boiler horsepower, and in this volume from 1.5 to 2.5 lb of oil per hour can properly be burned. This corresponds to an average liberation of about 38,000 Btuh per cu ft. At times much higher fuel rates may be satisfactory. For best results, care should be taken to keep the gas velocity below 40 fps. Where checkerwork of brick is used to provide secondary air, good practice calls for about 1 sq in. of opening for each pound of oil fired per hour. Such checkerwork is best adapted to flat flames, or to conical flames that can be spread over the floor of the combustion chamber. The proper bricking of a large or even medium sized boiler for oil firing is important, and frequently it is advisable to consult an authority on this subject. It is essential in combustion chamber design to prevent flame impingement upon either metallic or firebrick surfaces. Manufacturers of oil burners usually have available detailed plans for adapting their burners to various types of boilers. Such information should be utilized.

Controls

The control of oil-fired equipment is discussed in the section Controls for Automatic Fuel-Burning Equipment.

COMMERCIAL AND INDUSTRIAL OIL BURNERS

Oil-burning equipment for commercial and industrial applications is usually designed for burning the lower cost heavy fuel oils such as U. S. Commercial Standard Grades Nos. 4, 5, and 6. The viscosity of these oils is much greater than that of the lighter domestic grades and, therefore, the equipment required for satisfactory storage, pumping, and combustion differs greatly from that used in the typical domestic oil-burning system.

Both the initial cost and the operating cost of an oil-burning system may be affected materially by the characteristics of the industrial fuel oil to be used. These characteristics should, therefore, be given careful consideration when preparing the specifications of the fuel oil for which the system is to be designed.

Classification of Burners

Oil burners are usually classified according to the method used for atomizing the oil as (1) horizontal rotary-cup atomizing, (2) mechanical pressure-atomizing, (3) steam-atomizing, and (4) air-atomizing.

Horizontal Rotary-Cup Burner

In this type of burner, oil is delivered into a horizontal cup that is rotated at high speed. As the thin film of oil is spun from the rim of the cup, it enters a cone of high velocity primary air where very effective atomization is obtained. In most applications secondary air for combustion is supplied by natural draft through checkered openings in the floor of the combustion chamber. In some applications, however, the secondary air is admitted through openings surrounding the burner nozzle and may be supplied by forced draft.

The rotary-cup burner has been the most popular type in the capacity range from approximately 25 to 500 boiler horsepower. Its principal advantages are that it is a self-contained integral unit; it is readily adaptable to manual, semi-automatic, or fully-automatic control; and the firing rate may be easily modulated through a wide range while maintaining high combustion efficiencies. These burners are frequently used for firing packaged steam generator units.

Mechanical Pressure-Atomizing Burner

In this burner oil is atomized by passing it through a specially designed nozzle under pressures of approximately 100 to 300 psig. The air for combustion may be supplied by either natural or forced draft, and is usually admitted through an air register surrounding the burner nozzle or through checkered openings in the floor of the combustion chamber. This burner is popular for marine service and for large capacity multiple installations. It is not readily adapted to fully automatic operation.

Steam-Atomizing Burner

High-pressure steam is used in this burner for atomizing the oil. Oil is delivered to the nozzle at pressures ranging from approximately 5 to 50 psig, and steam at approximately 50 to 150 psig is admitted to the nozzle by various methods to assist in the atomization. Combustion air is usually supplied by natural draft through checkered openings in the floor of the combustion chamber or through an air register surrounding the nozzle. This burner is relatively low in first cost but is not adapted to fully automatic operation or wide variations in firing rate.

Air-Atomizing Burner

The air-atomizing burner is similar to the steam-atomizing type, except that air under pressure instead of steam is used for atomization. High-pressure air-atomizing burners use air pressures from 30 psig upwards and can operate at oil pressures and preheat temperatures in the same range as steam-atomizing burners. Low-pressure air-atomizing burners require air pressures of ½ to 5 psig and oil pressures from 5 to 20 psig. This latter type of burner requires a slightly lower oil viscosity at the nozzle for good atomization than either the high-pressure air or steam-atomizing burner.

STORING AND HANDLING HEAVY FUEL OILS

Preheating of Heavy Fuel Oils

Unlike the lighter grades of fuel oils that can be pumped, atomized, and burned efficiently without prior preheating, the heavier grades of residual fuel oils require conditioning by the application of heat before use. Preheating is employed to reduce the viscosity of the oil so that it can be pumped and atomized properly by the burner. The function of the burner is to atomize the oil and mix it thoroughly with the proper amount of air for prompt ignition and efficient combustion. The optimum viscosity will vary from 80 to 450 seconds Saybolt Universal viscosity, with the type of burner, and is reached at different temperatures for different grades of oil. The range of recommended atomizing viscosities is about as follows for normal grades of oil:

Type of Burner	Range of Atomizing Viscosities
Mechanical-Atomizing	100–300 SSU
Steam and High-Pressure Air-Atomizing	150–250 SSU
Rotary-Cup-Atomizing	150–450 SSU
Low-Pressure Air-Atomizing	80–90 SSU

Table 1 lists temperatures needed to bring various oil viscosities to the proper atomizing levels. These can be used with some variation to suit individual operations.

The correct degree of preheat must be used for each grade of oil. Underheating or overheating affects the terminal vis-

Table 1 . . . . Preheating Temperatures to Obtain Suitable Viscosities for Atomizing

Viscosity of Oil[a]		Oil Temperature (Fahrenheit) Required				
		Desired SSU Viscosity				
In SSF at 122 F	In SSU at 100 F	100	150	200	300	450
..	100	100	80	70	61	50
..	150	120	100	90	77	66
..	200	135	110	100	87	75
21	300	150	128	115	100	88
26	400	160	138	128	108	96
30	500	170	145	133	115	102
39	750	185	160	147	126	114
50	1000	190	168	155	133	120
60	1200	200	175	160	138	125
75	1500	205	180	168	145	132
100	2000	215	190	175	150	137
115	2500	220	195	182	156	143
135	3000	225	200	187	160	146
145	3500	229	205	190	162	150
160	4000	235	208	194	165	152
170	4500	237	212	197	167	155
190	5000	240	215	200	168	157
200	5500	245	218	204	172	160
220	6000	248	220	208	175	162
260	7000	250	225	210	177	165
285	8000	254	227	214	180	167
320	9000	258	230	216	183	169
342	10,000	260	235	218	186	171

[a] SSF = seconds Saybolt Furol viscosimeter. SSU = seconds Saybolt Universal viscosimeter.

From *Fuel Oil Manual*, by Paul F. Schmidt (The Industrial Press) 1951, p. 105. Columns for 300 and 450 viscosity from Davis Engineering Corp.