The prime essentials of good furnace design are: correct proportions, moderate combustion rate, adequate furnace volume and sufficient flame clearance. If these factors are properly compensated for and provision is made for the proper mixing of the gases bituminous coal stokers will operate smokelessly. In those stokers which are operated intermittently, however, some smoke may be produced during the *off* periods.

Combustion Adjustments

Satisfactory stoker performance may be secured by regulating the coal feed and the air supply so as to maintain, as nearly as possible, an ideal balance between the load demand and the heat liberated by the fuel. When the coal is consumed at about the same rate as that which it is fed this balance exists and uniform fuel bed conditions will be found. Under such conditions no manual attention to the fuel bed should be required other than the removal of clinker in those stokers which operate on this principle of ash removal.

Since complete combustion is not obtained in stoker furnaces receiving only the air theoretically required, it is necessary, even under the best of conditions, to supply from 30 to 50 per cent excess air to obtain desired combustion results. Due to the variable characteristics of solid fuels in burning, consideration must be given to a number of factors which affect the maintenance of the combustion conditions wanted.

The specified rate of coal feed of a stoker may vary due to changes in the bulk density of the coal dependent upon: (*a*) the size of coal, (*b*) distribution of size in the coal, (*c*) segregation of coal in the stoker hopper, and (*d*) friability of the coal.

The following factors may affect the rate of air supply: (*a*) changes in fuel bed conditions and resistance, (*b*) changes in furnace 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 (*c*) changes in air inlet adjustments to the fan.

Many domestic bituminous stokers now incorporate some method of automatic control which compensates for changes in fuel bed resistance. Since a secondary source of air due to leakage is present in most installations, the use of an automatic draft regulator to maintain the furnace draft at about 0.05 in. of water is desirable. This is quite important with intermittently operated stokers. Some fuel is burned by natural draft in the *off* periods, when fuel is not being fed, and it is essential that the burning in these periods be controlled. With excessive draft, due either to fan pressure or chimney pull, an increase in the discharge of soot and fly ash from the combustion chamber will result.

Measurement of the Efficiency of Combustion

As efficient combustion is based upon a certain percentage of excess air, it is possible to determine the results by analysis of the gases formed by the combustion process. An Orsat apparatus can be used to determine the percentage (by volume) of the carbon dioxide (CO_2), oxygen (O_2) and

carbon monoxide (CO) in the flue gases. Due to variations in the fuel bed and rate of burning of stoker-fired solid fuels it is not sufficient to analyze a *grab* sample. A continuous gas sample drawn at a constant rate throughout an operating period of reasonably long duration should be used.

A CO_2 reading of 12.5 to 14 per cent indicates that the excess air supplied is in the range of 30 to 50 per cent. The presence of CO indicates a loss due to improper mixing of the air and the gases of combustion. As an increase in excess air maintained during *on* periods will decrease the tendency toward smoke in the *off* periods of intermittently operated bituminous coal stokers, care should be taken that the delivery of air by the fan is great enough to avoid smoke.

Controls

The industry developed by stokers in Classes 1, 2, 3 and 4 has been due as much to the application of proper controls as to the stoker itself. This is especially true of Class 1 stokers because of their application to residential heating, a field wherein the majority of owners and users are not familiar with control problems or stoker operation.

The usual controls applied are as follows:

a. Thermostats (plain and clock).
b. Limit Controls (steam, vapor, vacuum, hot water, or air).
c. Stack Temperature or Time Controls (for actuating fires periodically).
d. Relay (for low voltage controls).
e. Safety or Overload Cutout (for protection against overload).
f. Low Water Cutout (steam, vapor and vacuum).

DOMESTIC OIL BURNERS

An oil burner is a mechanical device for producing heat automatically and safely from liquid fuels. This heat is produced in the furnace or firepot of hot water or steam boilers or warm air furnaces and is absorbed by the boiler, and thus made available for distribution to the house through the heating system.

With oil, as with any kind of fuel, efficient heat production requires that all combustible matter in the fuel shall be completely consumed and that it shall be done with a minimum of excess air. The combustion of oil is a rather rapid chemical reaction. Excess air provides an over supply of oxygen so that all of the oil, composed of carbon and hydrogen, will be completely oxidized and thus produce all the heat possible. The use of unreasonable quantities of air in excess of theoretical combustion requirements results in lowered efficiencies due to increased stack losses. Such losses, if not accompanied by unburned products of combustion (saturated and unsaturated hydrocarbons, hydrogen, etc.), may be offset somewhat by increasing the secondary heating surfaces of the heat absorbing medium, boiler or furnace.

Oil is a highly concentrated fuel composed mainly of hydrogen and carbon. In its liquid form oil cannot burn. It must be converted into a gas or vapor by some means. If the excess air is to be kept within efficient limits it means that air must be supplied in carefully regulated