fuel bed at one time. A portion of the glowing fuel should always be left exposed to ignite the gases leaving the fresh charge.

The importance of firing bituminous coal in small quantities at short intervals is discussed in a U. S. Bureau of Mines technical paper.[3] Better combustion is obtained by this method in that the fuel supply is maintained more nearly proportional to the air supply.

If the coal is of the caking kind, the fresh charge will fuse into one solid mass that can be broken up with the stoking bar and leveled from 20 min to an hour after firing, depending on the temperature of the firebox. Care should be exercised when stoking not to bring the bar up to the surface of the fuel, as this will tend to bring ash into the high temperature zone at the top of the fire, where it will melt and form clinker. The stoking bar should be kept as near the grate as possible, and should be raised only enough to break up the fuel. With fuels requiring stoking it may not be necessary to shake the grates, as the ash is usually dislodged during stoking.

It is acknowledged that it may be difficult to apply the outlined methods to domestic heating boilers of small size, especially when frequent attendance is impracticable. The adherence to these methods insofar as practicable, however, will result in better combustion.

Preventing Smoke

In general, time, temperature and turbulence are the essential requirements for smokeless combustion. Anything that can be done to increase any one of these factors will reduce the quantity of smoke discharged. Special care must be taken in hand-firing bituminous coals.

In the case of new installations, the problem of smoke abatement can be solved by the selection of the proper fuel-burning equipment and furnace design for the particular fuel to be burned, and by the proper operation of that equipment. Constant vigilance is necessary to make certain that the equipment is properly operated. In old installations the solution of the problem presents many difficulties, and may require a considerable investment in special apparatus.

Lower rates of combustion per square foot of grate area will reduce the quantity of solid matter discharged from the chimney with the gases of combustion. The burning of coke, coking coal, and sized coal from which the extremely fine coal has been removed, will not, as a general rule, produce as much dust and cinders as will result from the burning of non-coking coals and slack coals when they are burned on a grate.

Modern boiler installations are usually designed for high capacity per square foot of floor space, because such designs give the lowest cost of construction per unit of capacity. Designs of this type discharge a large quantity of dust and cinders with the gases of combustion, and if pollution of the atmosphere is to be prevented, some type of dust and cinder catcher must be installed.

Firing Methods for Semi-Bituminous Coal

The Pocahontas Operators' Association recommends the central cone method of firing, in which the coal is heaped on the center of the bed to form a cone, the top of which should be level with the middle of the firing door. This allows the larger lumps to fall to the sides, while the fines remain in the center and are coked. The poking should be limited to breaking down the coke without stirring. Grates should be rocked gently. It is recommended that the slides in the firing door be kept closed, as the thinner fuel bed around the sides usually admits the required air.

Firing Methods for Coke

Coke ignites less readily than bituminous coal and more readily than anthracite, and burns rapidly with little draft. In order to control the air admitted to the fuel it is very important that all openings or leaks into the ashpit be closed tightly. A coke fire responds rapidly to the opening of the dampers. This is an advantage in warming up the system, but it also makes it necessary to watch the dampers more closely in order to prevent the fire from burning too rapidly. In order to obtain the same interval of attention as with other fuels, a deep fuel bed always should be maintained when burning coke. The grates should be shaken only slightly in mild weather, and should be shaken only until the first red particles drop from the grates in cold weather. The best size of coke for general use, for small fire-pots where the fuel depth is not over 20 in., is that which passes over a 1 in. screen and through a 1½ in. screen. For large fire-pots where the fuel can be fired over 20 in. deep, coke which passes over a 1 in. screen and through a 3 in. screen can be used, but a coke of uniform size is always more satisfactory. Large sizes of coke should either be mixed with fine sizes or broken up before using.

SECONDARY AIR

When bituminous coal is hand-fired in a furnace, the volatile matter in the fuel is driven off by heat leaving coke on the grate. The product of combustion of the coke is CO_2 and under certain conditions some CO may arise from the bed. The combustion of the volatile matter and the CO may amount to the liberation of from 40 to 60 percent of the heat in the fuel in the combustion space over the fuel bed.

The air that passes through the fuel bed is called *primary air*, and the air that is admitted over the fuel bed in order to burn the volatile matter and CO is called *secondary air*.

This process of combustion is illustrated in Fig. 1.[4] The free oxygen of the air passes through the grate and the ash above it, and burns the carbon in the lower 3 or 4 in. of the fuel bed forming carbon dioxide. This layer noted as the oxidizing zone, is indicated by the symbols CO_2 and O_2. Some of the carbon dioxide of the oxidizing zone is reduced to carbon monoxide in the upper layer of the fuel bed, noted as the reducing zone and indicated by the symbols CO_2 and CO. The gases leaving the fuel bed are mainly carbon monoxide, carbon dioxide, nitrogen, and a small amount of free oxygen. Free oxygen is also admitted through the firing door in an attempt to burn carbon monoxide, as well as the volatile combustible distilled from the freshly fired fuel.

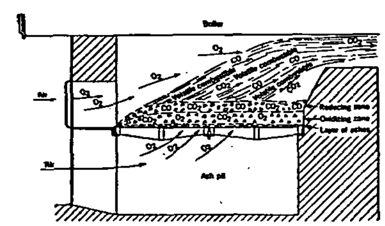

Fig. 1 . . . . Combustion of Fuel in a Hand-Fired Furnace

Size of the fuel is a very important factor in fixing the quantity of secondary air required for non-caking coals. With caking coals it is not so important, because small pieces fuse together and form large lumps. Fortunately, a smaller size fuel gives more resistance to air flow through the fuel bed, and thus automatically causes a larger draft above the fuel bed. More secondary air is drawn through the same slot openings, but, nevertheless, the smallest size of fuel will require the largest secondary air openings. For certain sizes of fuel, no secondary air openings are required, and for large sizes, too much excess air may pass through the fuel bed.

In general, the efficiency of domestic hand-fired furnaces and boilers burning either anthracite or bituminous coal, can be increased for an hour or two after firing, if some secondary air is admitted through slots of the fire door. However, unless the slots are closed when secondary air is no longer beneficial, the decrease in efficiency during the remainder of the firing cycle, because of excess air, may more than offset the gain resulting from the secondary air at the beginning of the firing period. Unless the secondary air can be readjusted between firings, it is probable that a greater average efficiency will be obtained for domestic hand-fired devices by leaving the secondary air slots closed at all times. There is usually an appreciable amount of air leakage around the firing door and secondary air slots of domestic furnaces and boilers.

Draft Requirements for Coal and Coke Firing

The draft required to effect a given rate of burning the fuel is dependent on the following factors: (1) kind and size of fuel, (2) grate area, (3) thickness of fuel bed, (4) type and amount of ash and clinker accumulation, (5) amount of excess air present in the gases, (6) resistance offered by the boiler passes to the flow of the gases, and (7) accumulation of soot in the passes.

Insufficient draft will necessitate additional manipulation of the fuel bed, and more frequent cleanings to keep its resistance down. Insufficient draft also restricts the control that can be accomplished by adjustment of the dampers. For draft requirements see Chapter 36.

Draft Regulation for Coal and Coke Firing

Since heating load demands vary in most installations, it is necessary to vary the rate of fuel burning. The maintenance of the proper air supply for the various rates of burning is accomplished by regulation of the drafts. Methods of draft regulation used for solid fuel are shown in Fig. 2.

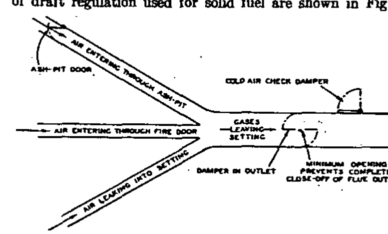

Fig. 2 . . . . Methods of Draft Regulation in a Hand-Fired Furnace

The air enters through the ashpit draft door, firing door, and by leakage through the setting, whereas the gases leave only through the outlet. By throttling flue gases with the damper in the outlet all the air entering by each of the three intakes is reduced in the same proportion, thus maintaining about the same percent of excess air. If inlet air is controlled by the ashpit draft door, the air admitted through the ashpit is reduced, while it is increased through the other two intake openings, resulting in an increase of excess air. A considerable increase in the efficiency of hand-fired furnaces and boilers can be realized by regulating the air supply by means of the damper in the outlet instead of the ashpit damper. Use of the ashpit damper is required, of course, for low rates of combustion. The cold air check damper is to be used only when chimney draft is excessive. It is normally closed unless the rate of combustion cannot be controlled by closing of the outlet and ashpit dampers.

Furnace Volume for Coal and Coke

The furnace volume is influenced by the kind of coal used. Bituminous coals, due to their long-flaming characteristic, require more space in which to burn the gases of combustion completely than do the coals low in volatile matter. For burning high volatile coals, provision should be made for mixing the combustible gases thoroughly, so that combustion is complete before the gases come in contact with the relatively cool heating surfaces. An abrupt change in the direction of flow tends to mix the gases of combustion more thoroughly. Anthracite requires comparatively little combustion space.

CLASSIFICATION OF FUEL OILS

Fuel oils are mixtures of hydrocarbons derived from crude petroleum by refining processes. Crude oil is distilled in towers at atmospheric pressure to produce gasoline, naphtha, kerosine and gas oil, and leave straight-run residues. The straight-run residues are distilled under vacuum to produce heavy distillates. The vacuum-flashed residue remaining can then be thermally cracked to produce more gasoline, cracked naphtha, cracked distillates, and cracked residue. The exact processes used depend on the proportions of the various end products desired, and to some extent upon the composition and characteristics of the crude oil.

Fuel oils may be designated as straight-run, thermally-cracked, catalytically-cracked, or blended, depending on the refining process used to produce them. Straight-run fuels are those produced by distillation under atmospheric pressure without decomposition of the hydrocarbons by cracking. Thermally-cracked fuels are those produced by a cracking process involving elevated temperatures (850–1100 F) and pressures (300 psig) to decompose the heavier hydrocarbons. Catalytically-cracked fuels are those produced with the aid of an alumina-silica catalyst in the cracking process at lower pressures than those used for thermal cracking. Blended fuel oils are mixtures of any of the above three types.

Grade Classification of Fuel Oils

Fuel oils are most commonly classified by dividing them into grades in accordance with the *Commercial Standard* (CS12-48) entitled *Fuel Oil* published by the *U. S. Department of Commerce*. These specifications, given in Table 4, conform to *ASTM Materials Specifications for Fuel Oils* D 396 – 48. Table 4 also shows specifications for PS 300 and PS 400 fuel oils which are numbers used in the Pacific