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THE DESIGN AND OPERATION OF UNDERFEED STOKERS

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This paper describes briefly the distinctive features of the single- and multiple-retort types of underfeed stokers, giving illustrations of a number of each type as well as particulars regarding their operation and results that have been obtained. Emphasis is laid on the importance of proper adjustment of the secondary coal feed, to prevent clinker and ash depositing at the lower end of the retorts, and on draft control not too responsive to momentary variations in boiler conditions. Underfeed stokers are said to be particularly adapted to bituminous and semi-bituminous coals, and for carrying sudden overloading. Clinkers are a necessary result of the high temperatures secured, and different means for preventing their adhesion to the side walls are discussed. The relative merits of various fans are considered, and a table of setting heights is given.

Underfeed stokers are so designed that coal is fed from beneath the burning fuel. This is accomplished by feeding through retorts with adjustments so that the fuel bed is replenished throughout the length of the retort. The main feed from the coal hopper is accomplished with rams of fixed displacement so that the amount of fuel fed per stroke is a definite amount for a given coal, and therefore the amount fed per hour is accurately controlled by regulating the speed at which the rams are operated.

SINGLE-RETORT STOKERS

2 The first development of this type was the single-retort underfeed stoker. This consists essentially of a horizontal retort, into which fuel is fed from the hopper and distributed throughout the length of the retort. Tuyeres are placed around the edge of the retort and through these air is supplied to the fuel under pressure from a fan. Dead plates or dump plates are placed on each side of the retort, from which the ash and refuse

are removed. For wider furnaces, intermediate inclined movable grates or tuyeres are placed between the retorts and the dump plates. These serve the purpose of providing more grate surface and also of depositing the ash and refuse on the dump plate.

3 Single-retort underfeed stokers do not require large ash-pits and ash tunnels below the boiler-room floor. They are cleaned of ash and refuse by dumping into shallow ashpits, which are depressed slightly below the floor line, and withdrawing the ash and refuse through doors in the boiler front at floor level, or by

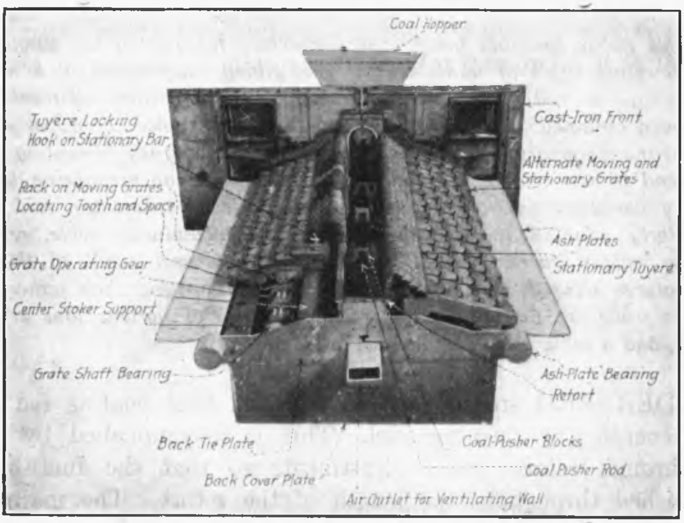

Fig. 1 Sturtevant Single-Retort Underfeed Stoker

withdrawing the ash from the dead plates through doors in the boiler front.

4 These stokers are also particularly adaptable to installations in which more than two boilers are placed in a battery, since side doors are not necessary to their operation. Boiler plants may then secure the advantages of the underfeed type of stoker without the expense of excavation and without being limited as regards arrangement of boilers.

5 Single-retort underfeed stokers are now being manufactured and marketed by five concerns, Figs. 1 to 5, inclusive, showing the various makes and their distinctive features.

MULTIPLE-RETORT STOKERS

6 The multiple-retort stoker is a development of the single-retort and consists of a number of single retorts placed close together and inclined with the ash discharge at the rear. As the coal is burned the ash is formed on top of the fuel bed and is floated to the rear and deposited on dump plates or into crusher pits from which it is readily removed. The continuous ash discharge consists of rotary toothed crushers placed at the rear of the stoker and set low so that a large, deep pit is formed for receiving the ash and burning out the last of the combustible material.

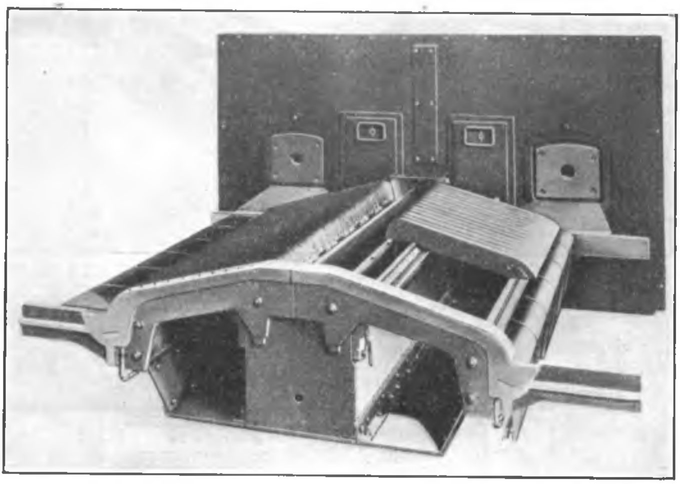

Fig. 2 Type E Single-Retort Underfeed Stoker

7 The secondary coal feed, that is, the feed from the retort to the fuel bed, is obtained in various ways. The Taylor stoker uses additional rams similar to the coal-feeding ram, which are placed in the bottom of the retort. The retort inclination is such that the rams are reciprocated horizontally. The Westinghouse and the new Frederick stokers have a lesser inclination, and the secondary coal feeding is accomplished by large wedge-shaped castings placed in the bottom of the retort. These are reciprocated on an inclination corresponding to the slope of the bottom of the retort.

8 The Jones and Detroit stokers have similarly shaped retorts, and the secondary coal feed is obtained by small wedge-shaped

pushers which are reciprocated horizontally in the bottom of the retort. The Riley stokers accomplish the secondary feeding by

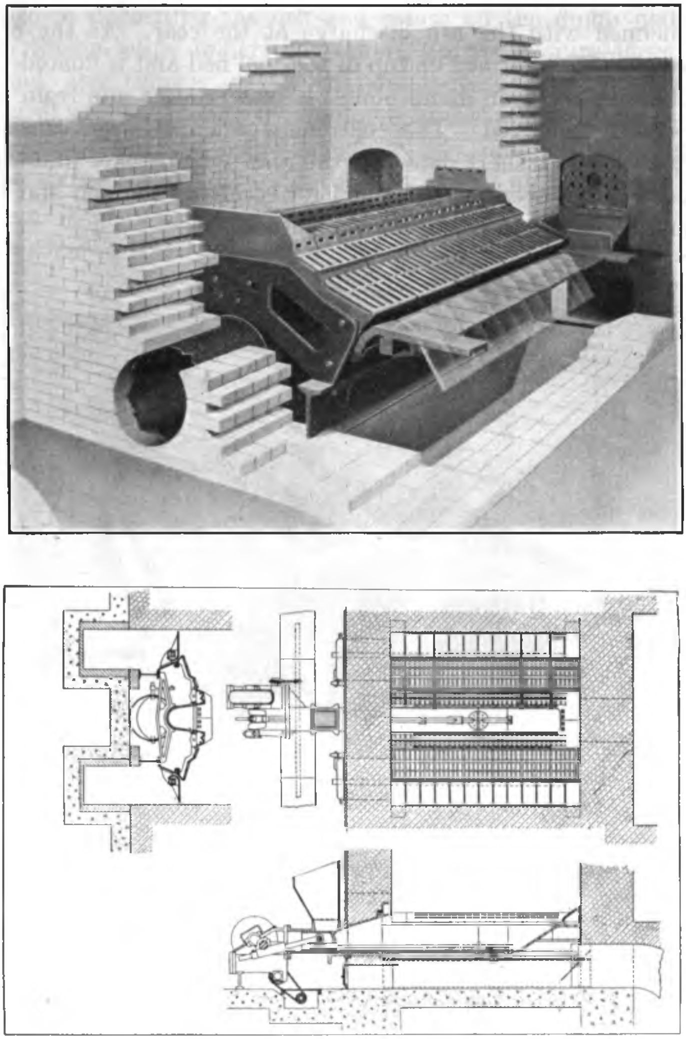

FIG. 3 DETROIT SINGLE-RETORT UNDERFEED STOKER

reciprocating the retort sides and the tuyeres. They also vary in the angle at which the tuyeres are placed — from horizontal in the case of the Detroit to 25 deg. in the Taylor stoker.

9 Tuyeres are placed between the retorts, and serve to convert the static head of air into velocity and direct the flow of air through the fuel bed. The tuyere designs naturally are different in each stoker.

10 All designs are for forced draft and cannot be operated at any appreciable capacity with natural draft. The air for combustion is circulated beneath the furnace parts and thereby cools these parts before being discharged through the fuel bed.

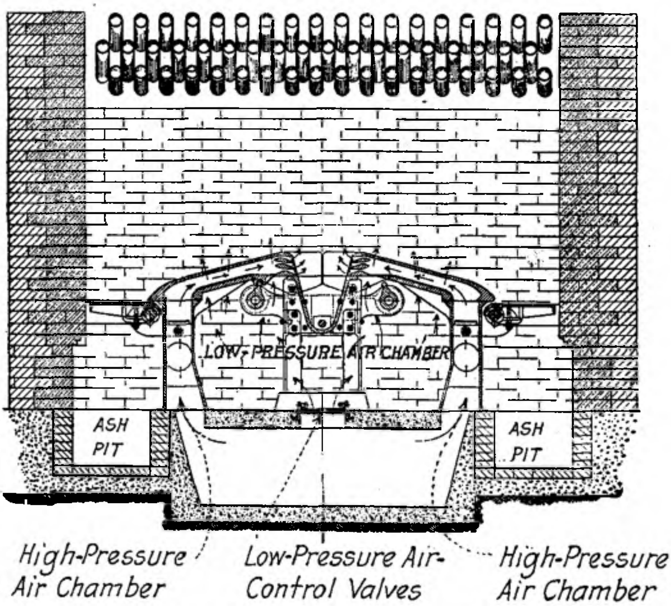

Fig. 4 Roach Single-Retort Underfeed Stoker

11 Figs. 6 to 11, inclusive, show cross-sectional views of the various makes of this type of stoker, and their essential differences in design.

OPERATION OF UNDERFEED STOKERS

12 The operation of underfeed stokers is essentially as follows: The incandescent burning fuel is on top and is replenished throughout the entire retort length from beneath. As the coal emerges from the retort it is coked and spreads over the tuyeres, forming a homogeneous fuel bed across the entire furnace width. As the fuel approaches the surface the volatile matter is completely distilled off

and the fuel completely coked. The surface consists of a layer of incandescent burning coke. The air for combustion is introduced near the point where the fuel emerges from the retort. As the volatile gases are liberated they are thoroughly mixed with air. As the mixture passes up through the fuel bed, higher-temperature zones are reached and complete combustion of the volatile gases takes place when they pass through the white-hot coke at the surface.

13 Smokeless combustion is obtained without the use of special mixing or ignition arches or special brickwork construction. As the fuel bed is replenished from beneath the surface, the burning incandescent coke which is on top is slowly moved toward the dump

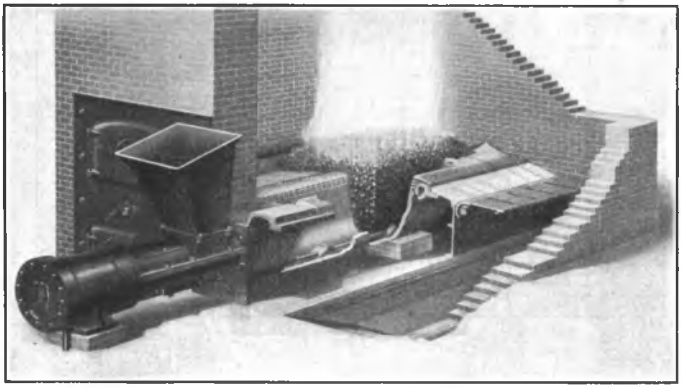

Fig. 5 Jones Single-Retort Underfeed Stoker

plates. As the ash is formed it is floated on the surface and is eventually deposited on the dump plates.

14 The control of the fuel bed is obtained by adjustments of the secondary coal-feeding arrangement. For good operation it is essential that the fuel bed be so controlled that the replenishing coal emerges from the retort through its entire length; the lesser amount being fed from the rear end of the retort.

15 With low-grade western coals more fuel must be discharged from the rear end of the retort than with the high-grade eastern fuels. In general, the greater the quantity of ash in the coal, the longer should be the stroke of the secondary fuel-feeding mechanism.

16 If insufficient coal is fed from the lower or rear end of the retort, the ash, instead of being carried on to the dump plates, is deposited at the lower end of the retorts, and as high fuel-bed

temperatures are always obtained the ash is clinkered and when deposited at this point it blocks the air discharge. After a short interval, fuel from the upper part of the retort, which is not coked, is deposited over this clinker formation and then avalanches on to the dump plates. With this condition of fuel bed it is impossible to secure good results or good operation. With proper strokes of

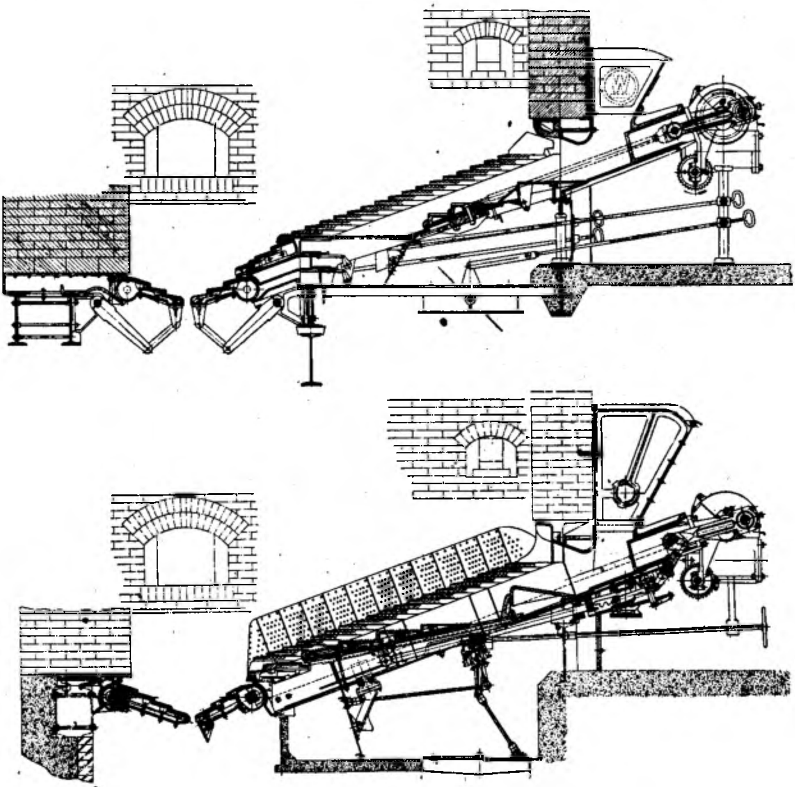

FIG. 6 WESTINGHOUSE MULTIPLE-RETORT UNDERFEED STOKERS

(Above, standard stoker; below, new model.)

the secondary coal-feeding mechanism this condition can be eliminated, as with the proper amount of coal being fed from this section of the retort the ash and clinker can never be deposited at this point. This is really the important adjustment to be made for various grades of coal, and it probably receives less attention from plant operators than any other variable. When properly adjusted the fuel bed is automatically maintained clean, and high rates of combustion can be obtained.

17 With the underfeed stoker properly adjusted, fresh fuel will be fed up throughout the full length of the retort. Green fuel moving upward with respect to the tuyeres tends to keep them buried, and consequently the ironwork is in the comparatively cool zone of the fuel bed. For this reason the maintenance is low on underfeed stokers.

18 With the underfeed system of combustion the excess air required can be reduced to a minimum, which means that high fuel-bed temperatures are obtained. The fuel-bed temperature will probably always exceed the ash-fusion point of any of our coals.

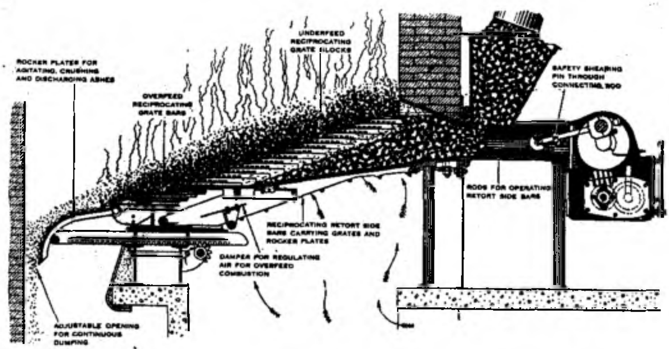

Fig. 7 Riley Multiple-Retort Underfeed Stoker

This means that clinker must be formed in order to secure the best combustion results.

19 These stokers are designed to handle clinker and maintain the fuel bed clean at all times and it is the duty of the operators to keep them so adjusted that they will maintain the fuel bed free of clinkers.

RESULTS SECURED

20 The stokers are particularly adapted for burning bituminous and semi-bituminous coals. However, with only slight modifications, lignites and coke breeze are also burned with excellent results.

21 With the thoroughly coked thick fuel beds carried, this apparatus is very quick in responding to load demands. Under running conditions the boiler capacity can easily be doubled almost

instantaneously. From a banked-fire condition, loads equivalent to 200 per cent of boiler rating and over can be picked up in a few minutes.

22 Standardization and interchangeability of parts have been accomplished to a considerable extent, especially of machined parts, and an effort has been made to simplify and reduce parts necessary to be stocked for replacement. Wherever possible, improvements in design have been so made that the new improved parts will be inter-

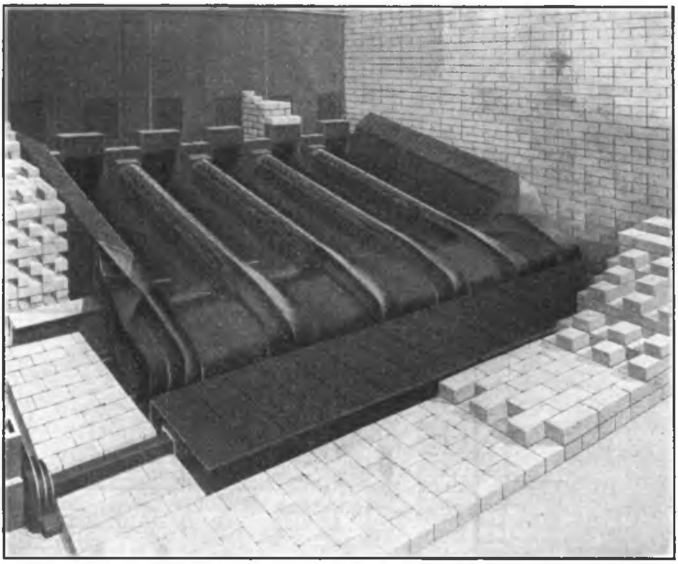

Fig. 8 Jones A-C Multiple-Retort Underfeed Stoker

changeable with the old parts and that no inconvenience will be occasioned by changing from the old to the new. When the new part is adopted it is automatically furnished on all future repair orders.

23 Many times the stoker manufacturer is handicapped by being forced to meet space limitations of the boilers. It is recommended that stokers be selected first, of the proper size and type to obtain the desired results, after which the boiler should be selected to meet the furnace requirements of the stoker.

REGULATION

24 Automatic regulation is receiving a great deal of attention at the present time, and improved equipment has been developed which is giving good results. It is doubtful, however, whether regulating apparatus will ever be developed to the point where adjust-

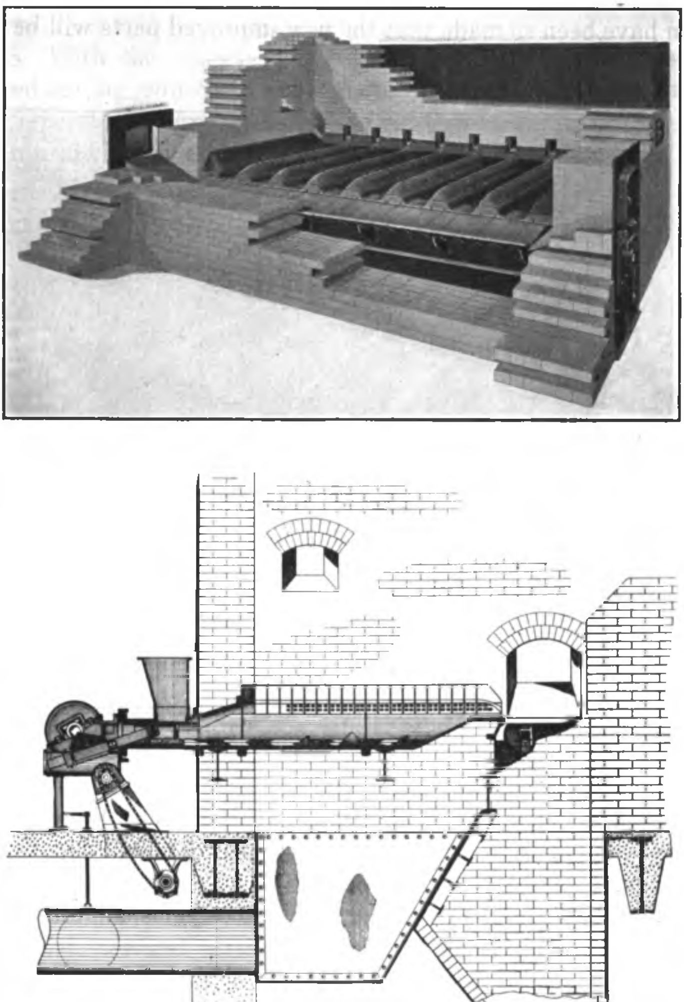

FIG. 9 DETROIT MULTIPLE-RETORT UNDERFEED STOKER

ments will not be required from time to time. These adjustments, it may be said, should only be made by an expert observer or fireman.

25 An ideal regulating equipment would be one which controlled all the variable elements in the proper proportion and in exact relation to the load, thereby obtaining a constant steam pressure. Such an equipment would, in addition to controlling the fuel, air supply, and drafts, also be required to control the feedwater in proportion to the load.

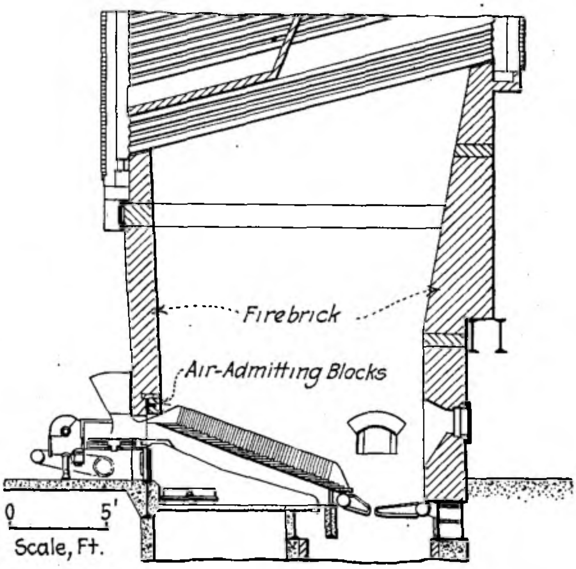

Fig. 10 New Frederick Multiple-Retort Underfeed Stoker

26 Practically all regulating systems in use at the present time are controlled by variations in the steam pressure. The damper regulator is very sensitive to slight changes in steam pressure, and unless its action is retarded by some means, hunting will take place, causing rapid and wide variations in the air pressure. Much better fuel economy is obtained by eliminating the rapid fluctuations in air pressure. This is accomplished by damping the regulator so that a greater steam-pressure variation is required to operate it through its complete stroke.

27 Fig. 12 shows an air-pressure and a steam-pressure chart from a boiler and furnace installation with such an equipment. The

Jones fluid-operated rams are controlled by a Cole automatic valve for each cylinder. This valve is operated from a power source, usually driven from the fan or the fan engine. It is possible to obtain a number of different adjustments for the rate of turning this automatic valve, so that the rate of feeding fuel can be varied for each retort; in fact, all the retorts can be arranged to feed at one speed or at eight different speeds. Furthermore, each valve can be operated by a hand crank, so that the coal can be fed into the retort in very large quantities at any time it is required.

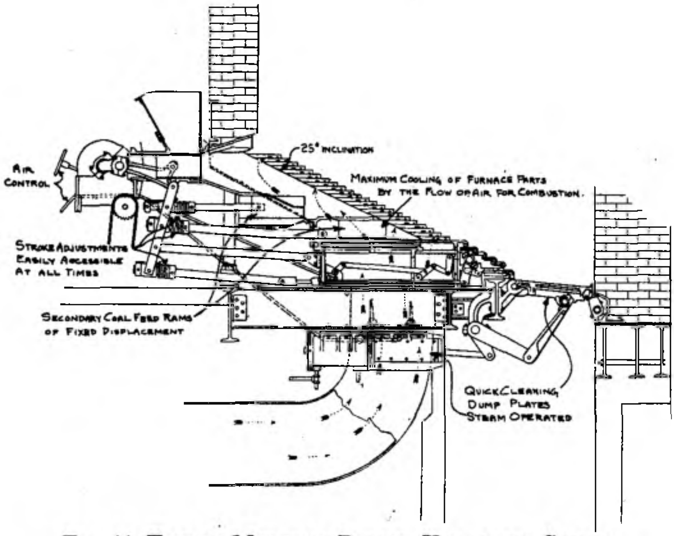

FIG. 11 TAYLOR MULTIPLE-RETORT UNDERFEED STOKER

FANS

28 There are several types of fans used in stoker service, each of which has different characteristics. (See Fig. 13.) The high-speed fan with narrow forward-curved blades (*a*) has a wide range of volume delivered with only slight variations in the static pressure, but is not well adapted for use on underfeed stokers. Due to this pressure characteristic, with two or more of these fans operating together it is practically impossible to keep them in parallel operation. It will be noted that this fan also has a very rapidly increasing horsepower requirement as the static pressure drops and the volume increases. This would only be satisfactory for a motor drive if an exceptionally large motor were used. If for any reason

the pressure should drop, the volume and horsepower would increase so much that the motor would be greatly overloaded.

29 The radial-tip fan (*b*), which is also a narrow-bladed high-

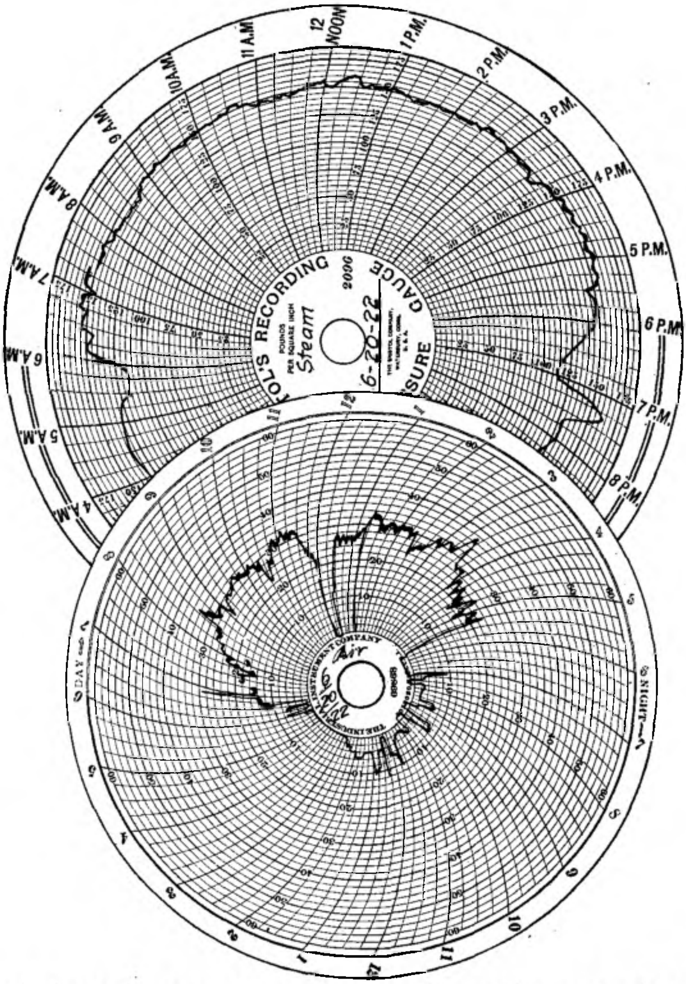

FIG. 12 STEAM-PRESSURE AND AIR-PRESSURE CHARTS FROM AN INSTALLATION WITH AUTOMATIC DAMPER CONTROL

speed fan, has very similar characteristics to the forward-curved-blade fan.

30 The partial-backward-curved fan (*c*) — high speed — and also the steel plate (*d*) — low speed — have characteristics which

are satisfactory, due to a steeper pressure curve. The horsepower increase is not abnormal for a drop in pressure, and these fans will operate in parallel and without trouble.

31 The full-backward-curved fan (*e*) with long blades, which is also a high-speed fan, has the best characteristics for stoker ser-

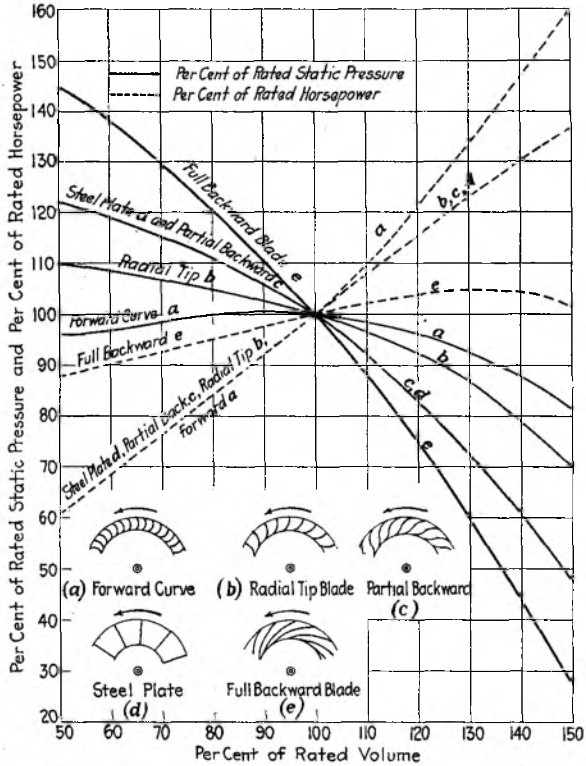

Fig. 13 Fan Characteristics at Constant Speeds

vice. It has a very steep static-pressure curve, together with a comparatively flat horsepower curve, and has the additional characteristic that after reaching the maximum horsepower any further increase in volume due to reduction of static pressure, will reduce the horsepower required. The smallest-sized motors can be used safely on this type of fan, and it also has the highest efficiency.

32 The steel-plate fans are usually direct-connected to vertical reciprocating engines. The high-speed fans are usually direct-

connected, when motor driven, while when turbine driven they are usually gear-connected, and sometimes direct-connected, to the turbine.

33 For a fan operating against a constant resistance the power varies as the cube of the speed, the static pressure as the square of the speed, and the volume directly as the speed. In underfeed-stoker practice, however, the resistance is not constant, so that the fans do not follow this law.

34 Fig. 14 shows in the dotted curves the volume and pressure characteristics in accordance with the constant-resistance law, while

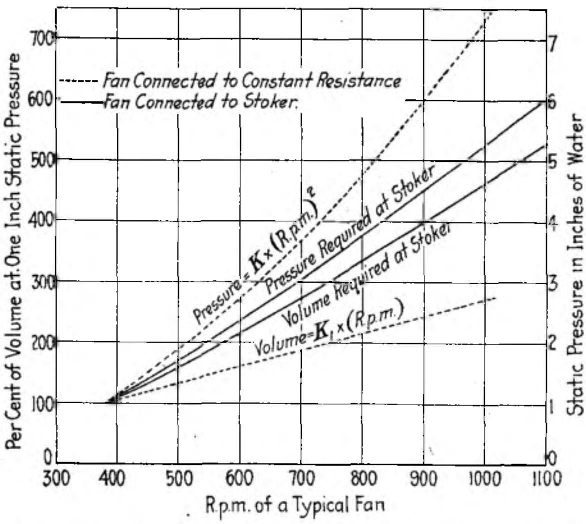

FIG. 14 RELATION OF VOLUME AND PRESSURE OF AIR TO FAN SPEED

the full-line curves show the volume and pressure characteristics at the stoker connection. These curves have been plotted from data obtained in actual stoker tests.

CLINKER PREVENTION

35 The most serious operating difficulties are caused by clinker adhesion to the side walls of the furnace. There are several successful methods for preventing this, the most popular one probably being that in which perforated firebrick blocks are located along the clinker line, through which air is blown from the stoker

air duct. The results from the use of these blocks have been generally satisfactory, although in some instances trouble has been caused by slag clogging the air holes. Care must be used in locating these blocks so that no free air is discharged above the fuel bed.

36 Another method of preventing side-wall clinker uses special high-side tuyeres through which air for combustion is discharged, these tuyeres extending high enough along the side walls to prevent the clinker adhesion to the brickwork.

TABLE 1 SETTING HEIGHTS FOR VARIOUS TYPES OF BOILERS EQUIPPED WITH STOKERS

(Min. = absolute minimum; P.M. = preferred minimum, i.e., the minimum heights recommended.)

Type of Boiler	Type of Stoker to be Installed													
	Multiple-Retort Underfeed		Single-Retort Underfeed				Side Overfeed		Front Overfeed		Chain Grates			
	Taylor, Westinghouse, Riley, Jones A-C, Detroit		Type E		Jones Single-Retort, Detroit Single-Retort		Murphy, Detroit		Roney		Natural Draft		Forced Draft	
	Min.	P.M.	Min.	P.M.	Min.	P.M.	Min.	P.M.	Min.	P.M.	Min.	P.M.	Min.	P.M.
Water-Tube:														
Horizontal	10′	12′	10′	12′	8′	10′	8′	11′	8′	10′	10′	12′	12′	14′
Inclined (Hor. M.D.)	7′	8′	6′	8′	6′	8′	5′	7′	6′	8′	6′	8′	7′	8′
Inclined (Vert. M.D.)	5′	6′	5′	6′	3′6″	5′	3′6″	5′	3′6″	5′	3′6″	5′	6′	8′
Vertical (Hor. M.D.)	3′	4′	3′	4′	3′	4′	3′	4′	3′	4′	3′	4′	3′	4′
Vertical (Vert. M.D.)														
150-hp.	4′6″	5′	4′6″	5′	4′6″	5′	3′3″	....	3′6″	4′6″	4′1″	4′7″	5′	5′ 6″
250-hp.	5′6″	6′	5′6″	6′	5′6″	6′	3′3″	....	3′6″	4′6″	4′1″	4′7″	5′	5′ 6″
500-hp.	6′	6′6″	6′	6′6″	6′	6′6″	3′3″	....	3′6″	4′6″	4′1″	4′7″	6′	6′ 6″
Horizontal Return Tubular:														
72-in.	8′	10′	8′	10′	7′	10′	7′	8′	6′	8′	7′	8′	8′	10′
84-in.	8′	10′	8′	10′	7′	10′	7′	9′	6′	8′	7′	8′	8′	10′

37 Still another method which has been very successfully applied in a number of plants, is one in which cast-iron side-wall air boxes are used. These are independent of the stoker structure, except through the air connections. The faces of the boxes toward

the fuel bed are made of small overlapping ribbed plates. These plates are solid so that no air is discharged through them. Air enters one end of the box from the stoker air chamber and is discharged under the tuyeres from the other end of the box; this air circulation being sufficient to prevent burning of the plates and the adhesion of clinker. These boxes should not be less than 10 in. wide.

38 Carborundum bricks are satisfactory for this purpose with

TABLE 2 DEFINITIONS OF SETTING HEIGHTS FOR VARIOUS TYPES OF BOILERS

Type of Boiler	Setting Height
Water-tube, horizontal...............	Floor line to bottom of header above stoker
Water-tube, inclined.................	Horizontal mud drum: floor line to center of mud drum
	Vertical mud drum: floor line to top of mud drum
Water-tube, vertical.................	Horizontal mud drum: floor line to center of mud drum
	Vertical mud drum: floor line to top of mud drum
Horizontal return tubular............	Floor line to under side of shell

some coals. However, when the ash contains much iron, carborundum brick is rapidly eaten away:

SETTING HEIGHTS

39 The Stoker Manufacturers' Association, in conjunction with the American Boiler Manufacturers' Association, have adopted minimum setting heights for all types of boilers which are given in Table 1. Setting heights for the different types of boilers are defined in Table 2.

40 A number of recent large boiler units have been set considerably higher than as specified in Table 1. The boilers of the new Hell Gate power station are set 21 ft., giving a furnace volume of 16½ cu. ft. per sq. ft. of grate surface, or 390 cu. ft. of furnace volume per 1000 cu. ft. of boiler heating surface.

41 Frequently the combustion space required is stated as a function of the coal-burning capacity. This is misleading since it leaves out of consideration all conditions imposed by the arrangement of the boiler baffles and stoker in relation to one another.

42 It is desirable to keep the velocity of the rising gases in the furnace as low as possible, but a larger horizontal furnace section, with consequent large volume, may not necessarily do this.

43 Ample height of the boiler above the stoker should be secured in order that combustion of the gases may be completed before they enter the tubes.

44 High setting heights impose a more severe service upon the brickwork. Extreme care must be used in designing the furnace walls, so that they will stand not only the high furnace temperatures, but also the load. It is common practice at the present time to expose all of the first few rows of boiler tubes to the radiant heat from the fuel bed. This gives lower furnace temperature and greater life to the brickwork.

45 No arch construction or special brickwork is required in the application of underfeed stokers, and in fact it is preferable not to have arches. On account of the differences in the coefficients of expansion of different kinds of brick, however, only one kind should be used in the furnace.

46 Proper provision must be made for taking care of the expansion as the setting heats up. The brick should be carefully sized so that thin joints can be obtained. Each brick should be dipped in a thin fireclay wash and tapped into place with a wooden mallet until it touches the bricks next to it.

47 Walls should never be so constructed that they overhang or lean toward the furnace. Walls which slope outwardly from the furnace will give much longer service.

DISCUSSION [1]

A. H. Blackburn. In drawing attention to the many types of underfeed stokers, Mr. Lawrence has omitted to mention the lateral-retort stoker brought out by The Under-Feed Stoker Company of America during the present year.

The novel feature of this stoker is that it feeds the coal in through a main retort extending from the front wall of the furnace to the bridge wall, with lateral retorts branching off the main or central retort at right angles as shown in Fig. 1.

The coal from the hopper is fed by a steam cylinder into the central retort, and the coal from this central retort is forced into each lateral retort by means of laterally operating pusher blocks operated by an auxiliary steam cylinder. The length and

[1] Applies to papers Nos. 1867 *a*, *b*, and *c*.

the timing of the stroke of these lateral pusher blocks may be varied and separately controlled, as the auxiliary cylinder is independent of the main cylinder.

This stoker is the same in principle as the multiple retort stokers, being practically two multiple-retort stokers placed back to back, fed by a main retort and dumping at the sides of the boiler. The coal is fed up underneath the entire fuel bed throughout the various lateral retorts, with a gradual rearward and upward progress of the coal. This is the only high-duty, side-cleaning stoker on the market in which the underfeed principle is wholly embodied.

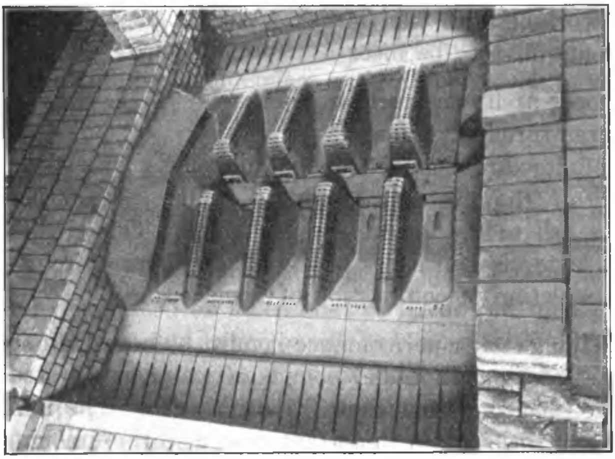

Fig. 1 Top View of Stoker Showing Arrangement of Five Lateral Retorts and One Main Retort

The number of strokes of the feed cylinders are controlled by two Jones automatic valves, which valves are regulated by the pressure of steam, so that the coal feed is in proportion to the demand for steam.

The front and back walls of the furnace are protected by high air-cooled tuyeres, the stokers having been designed for working continuously around 200 per cent boiler rating. The design of the stoker enables it to be installed without a basement and under low-set boilers that may be already installed.

J. M. Drabelle. In the central West, particularly in Iowa, there is a rather peculiar type of fuel available, namely low in heat value running 8500 to 9000 B.t.u. per pound as screenings. The ash content is very high, 20 to 35 per cent, and the ash easily fusible. To burn this certain definite furnace conditions must be met, namely an undisturbed fuel bed, a large furnace volume and a high ignition rate.

The chain-grate stoker, judging from several years of actual operating experience, is the only successful stoker for handling this type of fuel. Every stoker has its field of application and for high ash Western coals as above mentioned it is the only stoker that meets the requirements above stated.

Very considerable work has been done in connection with this problem working with Mr. Marsh. We have found the following requirements have to be met:

Proper arch construction
Large furnace volume
Definite direction of leakage air coming over the back end of the grate in order to reduce the carbon in the ash to the lowest possible value. This slight air leakage also furnishes additional secondary air for the completion of combustion of furnace gases.

In judging stoker performance it must be borne in mind that it is the total cost per thousand pounds of water evaporated and not percentage efficiency that must be dealt with. The maintenance problem is a serious and important one, also the amount of operating labor required. While some stokers may develop higher efficiencies, when the amount of auxiliary power required for the operation of fans and other special devices is deducted they do not present any real gain in efficiency on Iowa coal. The item of investment must also be borne in mind for this in turn determines fixed charges.

We have found over many years' experience that the chain-grate stoker gives sufficient flexibility in handling loads to take care of conditions in power plants in this state. For example, in one large railway power plant the chain-grate is successfully handling a widely fluctuating load made up of a combination of demands from an extensive street railway system and a large interurban network and the boiler efficiency in this plant runs for over the month well around 73 per cent.

The ideal chain-grate stoker, to my mind, would be a combined natural-draft and forced-draft stoker, operating under the normal conditions of the station on natural draft and over the peak load with forced draft, thereby reducing the amount of auxiliary power required to the absolute minimum, resulting in a lower cost per thousand pounds of water evaporated.

Walter N. Polakov. Quite apart from the excellence of design and construction of a mechanism, and altogether independent from it adaptability to fuel used, the success or failure of a stoker largely depends upon the mode of its use.

Sometimes it is claimed that a mechanical stoker is an automatic device and that by the virtue of its so-called automatic action the plant owner can " forget his power plant." It is only too often that this lullaby has its effect with telling results of shameless fuel waste.

A stoker is automatic only in so far as it replaces a certain amount of physical exertion by the substitution of mechanical power. For this reason alone the stoker attendant is no longer interested in how he can spare himself the pain of shoveling unnecessary coal into a furnace, and unless he has other stimuli he will let the stoker feed as much coal as it can and make as little steam as it may. Again, when *supplementing* a mechanical stoker, some automatic regulating devices are introduced, which as a rule control only one or a few detached factors, but never *the operation as a whole.* Worse yet, in a large number of cases, these automatic controllers are working *either a little behind the time* or make adjustments of conditions by *steps.* In both cases the consequences are that losses are increased coming and going. Even with oil firing I have on record cases where automatic regulators of merit had to be discontinued and manual control introduced in order to increase the evaporation.

In other words, no machine, however perfect, however automatic in its function, can replace the human intellect. On the other hand, there is a grave question in my mind whether it should, for, if we take from the operator the mental stimulus of thinking while he is working; if we will make him a mechanical adjunct to an automatic machine, we will invite trouble by trusting this vital process in industry not to man but to automatons.

What I have said is neither theory nor generalization. It is a summary of facts which came under my observation during the last score of years without a single exception. A few illustrations may be to the point:

Not many years ago, a public utility plant in central Pennsylvania (Warrior Ridge, Penn Central Light & Power Company) had hand-fired boilers with well-trained help and a reasonable array of instruments helping them in the intelligent performance of work. Under the stress of war conditions, the management installed, after raising boilers to suitable height, a certain approved type of stokers. What were the results? The average of three years of hand firing indicates the combined boiler efficiency of 72 per cent, the performance of the stoker on the acceptance test was higher than that, but in the daily operation a year after it averaged only something like 65 per cent.

Again, I may recall the case of a large manufacturing concern (The Celluloid Company) where mechanical stokers were working for several years at an efficiency averaging between 50 and 60 per cent. Stoker company experts and engineering construction companies were called in from time to time, but the results under the traditional form of management in the power house were never lasting enough to influence yearly, or even monthly averages. At last a change has been made, not in the equipment, but in the mental attitude of management, which resulted in the training of personnel, arousing intelligence in boiler room, in providing mental stimulus, with the outcome that the force dormant in human nature, the " lure of perfection," led them to competition with their own past. The efficiency of 50 to 60 per cent became a matter of sad memory, and during the last three or four years the combined stoker and boiler efficiency averaged 74 per cent.

There is still another type of cases which may be exemplified by an instance of a plant in New England. A well-known type of stoker was employed there under vertical boilers (at Lewiston Bleachery & Dye Works), and while the efficiency was as a rule slightly over 50 per cent, the nuisance of smoke and shortage of capacity led them to investigate the troubles. The same well-beaten path was followed; instruments were put in, man's interest aroused, instruction and training provided, stimuli created. Then it was found out that the load which eleven boilers were unable to carry under the old régime was carried safely and economically by only seven boilers. No smoke complaint, no clinker trouble, and the efficiency on the annual average showed a little better than 72 per cent.

The lesson to be drawn is this:

1 The best stoker is one which permits the largest amplitude of manual control
2 The best results can be secured from a stoker *only* when the management assumes responsibility, and
   a Does away with flapper-engineering that installs stoker without full assortment of instruments
   b Introduces intelligence into boiler rooms by training personnel through a long series of experiments, demonstrations and explanations, and
   c Elevates the man behind the stoker from the position of an automaton to a truly human class, where the lure of perfection reigns supreme.

J. R. Fortune. There should be some way of designating stokers other than by the terms "underfeed" and "overfeed." There is only one type of stoker that, in my opinion, can truly be described as overfed, and that is the sprinkling stoker, which is not very well known in this country but which is quite commonly used abroad. This is the only stoker in which the fuel is fed on top of the burning fire. The fuel in the stokers of the Murphy, Roney, and chain-grate types is always, in effect, underfed. In other words, there is a layer of fuel unignited close to the grate bars near the stoker hopper, and this is overlaid with fuel which is burning almost all the way to the feed opening of the stoker. The unignited fuel close to the grate bar may extend halfway down the grate.

It might be said that an underfed stoker is a stoker in which the fuel is fed beneath the burning fire, and under the air-feeding devices of the stoker. If we use this definition, the inclined multiple-retort stokers would not comply as the fuel is fed horizontally and practically parallel to the openings of the tuyeres.

If the design of the Murphy stoker is studied it is seen that the fuel is fed underneath some of the air-feed openings of the furnace, and it is a fact that some of the earlier designs of this stoker were provided with vertical tuyeres located in the feed openings as shown by Fig. 2 which discharged air into the furnace in a precisely similar manner to the method now used in the multiple retort stokers.

I suggest, therefore, that it would be a good plan to drop the designation of "overfeed" and "underfeed" from the mechanical stoker vocabulary.

ALEX. D. BAILEY. Mr Marsh's statements that "modern steam turbines called for greater capacities from boilers" is not the whole story. Turbine development has been in a way parallel with boiler development, and along with the development of these two major pieces of equipment has been the coincident development of all plant equipment. So far as the boilers themselves are con-

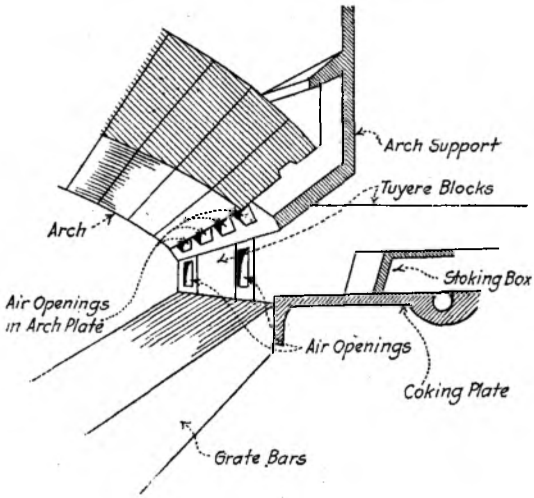

FIG. 2 TUYERE BLOCKS LOCATED IN THE FEED OPENING OF THE MURPHY STOKER

cerned, the demand for higher capacities has been occasioned by increased fuel costs and increased equipment costs, the latter due partly to higher pressures and partly to economic conditions.

That the boiler proper has shown itself capable of taking care of these rates of heat absorption without materially decreasing its efficiency is evidenced by the very marked development of stokers and other coal-burning equipment during the past few years. At no time in the past has the improvement been so marked or so rapid. The chain grate, which is probably one of the oldest forms of mechanical stoker known, has had to fulfill its part in this development in order to justify its existence, and the development of the forced-draft chain grate is the result.

For higher boiler capacities, increased gas volumes are essential, which means higher coal-burning capacities and rates. As the rate of coal-burning has definite limits, as has been proved, increases have been necessary in grate areas, resulting in the so-called over-stokering of boiler installations. Additional gas volume has also required additional furnace volume in order to assure proper combustion conditions. All this in turn has increased the investment cost of this equipment, which, together with the increased cost of fuel, has not only justified but made necessary the various refinements in stoker and furnace design by which maximum efficiencies are obtainable.

Just as the natural-draft chain-grate stoker has made possible the use of coals which were unsuited to existing types of stokers which were consequently cheap, so the forced-draft chain grate has made available not only low-grade fuels, but also coke breeze and smaller sizes of anthracite, which had not been previously considered suitable for power production. This economic saving alone justifies the improvement in chain grates.

Wm. R. Roney. We cannot say that the power users are responsible for all the troubles that arise in the boiler room, and we cannot say that the stoker builders are responsible for all. It is a question of united responsibility and the details of the burning of the coal, and how it is handled, be the power house large or small, are details of engineering outside of stoker-making. I feel that it is a question of responsibility, well-divided all the way from the humble fireman who shovels the ashes out of the ashpit, to the engineer who sits in his office and directs. Consequently we are — I say we, because I am not now in the stoker business, but as a stoker advocate I say we are responsible for a large part of what goes on in the boiler room and as the time goes on, we will be more and more responsible.

From my own experience in trying to make a stoker work against prejudice, ignorance, bad handling, bad fuel and bad conditions, I learned a good many things; but principally that the human element that handles the stoker, that handles the boiler-room, that handles and develops the power, is the most important of all.

David Moffat Myers. I would like first to supplement what Mr. Roney said with regard to the human element. I would like to put his remarks in engineering terms, and that can be done very simply. The efficiency of any process is equal to the efficiency of the mechanical equipment, multiplied by the efficiency of the human equipment.

I have five questions to ask.

1 In the underfeed stoker the coal is gradually elevated to the top zone of the fire bed, where it is subjected to the highest temperature of the fire which promotes fusion and clinker formation. What can be done about it?

2 We have been dealing with steam production on land. Approximately 67 per cent of all the coal mined goes to making steam on land. The bunker coal is a very small percentage, but these stoker builders seem very careful to avoid getting into the trouble of applying stokers to production of steam in vessels on the sea. It is a tough problem, but why should they avoid it?

3 I would like to hear the stoker manufacturers who are here today, tell me plainly what they think about automatic regulation. I have, when buying stokers, put this problem up to them: Here are people who promise to add 2 or 3 or 4 per cent to the efficiency of the stoker installation if you will install their system of automatic regulation. I have gone back to the stoker people from whom I am buying the stoker equipment and have told them that if they will add 1 per cent to the stoker guarantees, I will buy their equipment. They throw up their hands and are not interested. Why?

4 Mr. Lawrence gives a very interesting table showing the height of boiler setting recommended by the Stoker Association. Unfortunately, he does not relate those figures to the capacity rating expected from the boilers. The combustion space is a direct function of the rating from the boilers with a given fuel. The more coal burned per minute, the greater amount of combustion space necessary in order that a molecule of the fuel may remain a given length of time in that combustion space for complete combustion. Why not relate the height of boiler setting to boiler rating, or at least to pounds of coal per hour, for different kinds of coal?

5 Mr. Marsh gives a table of records obtained with chain-grate stokers. I am unable to find in that table any results of the burning of the fine sizes of anthracite which I would like to have for comparison with the results in other plants under my observation.

J. E. Woodwell. There is a stoker for every class of coal, and a class of coal for every stoker. That is to say, there is a certain furnace volume, rate of feed, and ash-fusing temperature which depend on definite qualities of the coal, and which determine the design of the stoker. So it is not a competition between the chaingrate and the underfeed or the overfeed, or the inclined-feed stoker for every location and condition. They all have their field, they all have their limitations. Recently we have discovered some valuable features of stoker design. We are just beginning to find out that one of the principal essentials of stoker design is furnace volume, and we are learning that when a boiler manufacturer or stoker manufacturer advises 300 to 400 per cent rating on peak, the owner of the boiler must expect an increase in replacement of furnace linings, etc., and have his boiler laid off for repairs. Therefore, I am an advocate of excess stoker capacity just as a reserve against frequent furnace repairs so that the boiler will be in service nearly 100 per cent of the time.

In regard to automatic control, I do not agree with Mr. Polakov. In our last station there is a system of automatic control which coördinates the draft fans, the stoker motors and the outlet damper of the boiler. The control is by steam pressure.

Manual control can, in my opinion, never equal automatic control under proper supervision.

Theodore Maynz. One point in the chain-grate stoker that we operators have to watch is the carbon in the ash. With some coals we can run with 35 or 40 per cent excess air and get good carbon, and we have to raise our air to 60 or 70 per cent with another coal before our total loss is at the minimum.

Another point is uniformity in the size of coal. In a stoker 12 or 13 feet wide, if the coal is not absolutely uniform, we will get coarse coal, as a rule, on the sides and that means excess air and a bad fuel bed. Therefore, with chain-grate stokers it is important to have the coal as uniform as possible. This is not easy. We can mix it up in the bunkers and by the time it gets to the coal hoppers, it is again segregated, the coarse going through the center and down the sides while the fine coals are packed about a foot from the wall to within a foot of the center. To obviate this trouble we are trying, and have had some success with, tilting and split gates.

Another point is the seal at the rear end of the stoker. This can be sealed in two ways. One way to seal it is by a bank of coal against the water back that cuts off a lot of the grate surface and seems to give a much higher carbon in the ash. Another method is an internal seal. We also seal it by means of ashes between the lower portion of the grate and the ashpit. If we run with too high a bank in the rear, that is, over 3 or 4 inches, we cannot get the right amount of carbon in the ash.

With a forced-draft chain-grate stoker, the dirt coming out from the front is a big objection. We have not been able, nor have the manufacturers of our stokers, been able to seal the front part of our stoker, and it makes almost an unlivable boiler-room.

I agree with Mr. Polakov that the stoker operator should be given proper instruments. They are absolutely necessary and the men appreciate them.

Stoker operators would like stoker manufacturers to solve the following problems:

- *a* To get a stoker that will burn practically all types of coal with uniform efficiency
- *b* The elimination of clinkers up the stack and slag on the lower tubes of the boiler
- *c* A clean boiler-room with stoker-fired boilers
- *d* Stokers with reliabilities of medium-sized turbines.

EDWIN LUNDGREN. I would like to answer some of Mr. Myers' questions. The reasons stokers have not been applied universally to marine practice are, first, that stokers must take coal from almost any port and hence very different kinds of fuels which may or may not burn satisfactorily. Another difficulty is the low space that is provided between the tubes of the boiler and the bottom of the ship, which makes it very difficult to install any but the horizontal type of stoker.

However, The Combustion Engineering Corporation have applied their type E stoker to several ships in Europe, and in most cases successful operation has been reported. There have been difficulties, I believe, with certain types of fuels, but the operators seem to think that the stoker can be made satisfactory for marine service.

Mr. Myers spoke about automatic regulation. It has been my personal experience that the best automatic control is a really intelligent fireman to whom has been given the simple proper instruments which will guide him in the operation of the stoker.

Of course, there are industrial plants which cannot afford this high-grade operator. In such cases, perhaps, automatic control with a hit-or-miss operation at the best, will give most satisfactory operation.

Albert A. Cary. In the summary of Mr. Marsh's paper, a rate of combustion of 40 to 45 lb. per sq. ft. of grate per hr. is mentioned, and in Par 47, 55 to 60 lb. per sq. ft. per hr. Such statements mean practically nothing. In a previous paper I stated that when a fuel carrying combustible gaseous matter is charged upon a hot fuel bed the gaseous matter is distilled and rises above the grate into the combustion chamber where it is burned. It is only the coke or fixed carbon that remains behind and is really consumed on the grate.

If we want to specify the capacity of a stoker by pounds burned per square foot of grate, it is practical to specify the pounds of fixed carbon per square foot of grate. There is no difficulty in burning high volatile coal at these higher rates of combustion, but there is difficulty with Georgia Creek or Cumberland.

One of the great troubles not spoken of in the paper on chain-grate stokers, and which has gradually been overcome, was the burning of the caking coals of the East. The difficulty was to get the coal on the grates, and getting it in a condition of non-caking coal such as occurs with the western coals.

The "rousting" and hand manipulation of overfeed stokers, spoken of by Mr. Bouton in Par. 12 of his paper, is the curse of this type of stoker. There is less of it done now than before, but it should be done away with in order to get the best results.

Alfred B. Carhart. It has been mentioned in the discussion that automatic control can maintain an average condition but only with the intelligent operator can adjustment be made to varying conditions so as to control the actual results of the moment, rather than making historical records to show what mistakes were made. We must have a guide for present operation, not merely a distant record in the office of the superintendent of the works, which shows the errors that have been made.

I think that too often the manufacturers of equipment, whether boilers or stokers, or any other automatic device, have made us believe that with the installation of such machinery, we could greatly increase our efficiency. No doubt it is so, and it is not a criticism, but rather a commendation on stokers, that their installation means not only greater combustion of coal, but also a double opportunity for loss and waste, which is not always properly recognized at the present time. We often wake up to it afterward in the actual operation.

We should take into account that having such a valuable piece of apparatus in our hands, we should take pains to see that it is intelligently used rather than believe that by the installation of such machinery we have rid ourselves of all future thought and trouble. There are still intelligent operators to be had in this country, and we do not have to depend upon the lumper and helper type, which is so often looked upon as the ideal labor in the operation of a stoker.

C. G. Spencer. This symposium has brought out very clearly the fact which we all knew, that each type of fuel must have a stoker adapted to it, and the furnace must be designed for that type only. Ever since war conditions came upon us, we have had brought to our attention that fact that we cannot get the type of fuel that we would like at all times. Instead of having, as Professor Breckenridge has pointed out, five types of stokers to burn 75 types of fuels, we need one type of stoker which will burn 75 types of fuel. This is the big problem ahead of fuel engineers at the present time.

H. G. Heaton For many years power station operators have experienced a great deal of trouble with the operation and maintenance of coal crushers, because they have to crush not only the coal but such foreign matter as comes through with the coal.

About a year ago we installed on one of the Commonwealth Edison Company's stations, a Bradford Breaker. This breaker contains a large cylinder about 12 ft. in diameter and 20 ft. long in which the coal is slowly rotated. This cylinder is perforated, and the sized coal drops out into a hopper. We find there is no possibility of getting coal that is not properly sized through the breaker. We have used 1½ in. holes for chain-grate stoker practice, and we believe that $1\frac{1}{4}$ in. may be a little better, as the result of the experience of one year at the Calumet Station with this apparatus.

As to the question of the stratification of the coal in the bunkers; the coal tends to pile up and stick together on the sides of the bunkers, with the result that it will avalanche and successively different sizes will be delivered into the grate. Therefore, it is necessary to exercise the greatest care in the design of bunkers, so as to prevent this action. I have seen coals that would stand almost vertically on the sides of the bunker and under such circumstances it is impossible to overcome the trouble.

As to the question of the distribution of coal to the stoker; my belief is that the best way to handle coal out of the bunker to the grate is with the swinging spout. We have tried out both spouts a number of years, but there will always be better distribution of the coal throughout the grate, if the spout is of the swinging type.

Henry M. Burke In justification of the remark made by Mr. Polakov about not believing in the automatic regulation of stokers, it might be well to mention a practical application which is really a justification of not only Mr. Polakov's remarks but of those who took issue with Mr. Polakov later.

As the operator of a 5,000-hp. industrial plant who has to watch the efficiency from day to day and answer to the treasurer who is spending the money for the fuel, I have found that the automatic control of the total plant is impossible from the standpoint of efficiency and I have also found that the control by manual means is impossible. The plant has been worked on a bonus scheme and we have found that the fireman is anxious to do so much work that when put on absolutely manually handled plan, he is taking care of too many operations to operate this plant most efficiently. We have found also that in operating the plant from the automatic control, that he is too prone to do nothing. Therefore we have worked out standards according to the loads carried by this plant, and have sectionalized the control, taking up the peak loads with manual control and carrying along the regular load by the automatic control.

J. B. Crane. The size of the coal for chain-grate stoker is very important. I have had no experience in burning bituminous coal on chain-grate stokers, but I have had considerable experience in burning the small sized anthracites, and have found that uniformity of size is essential.

On the question of furnace volume, we started in 1916 to put in boilers with four and a half cubic feet per rated horsepower, and there are very few recent installations that have gone as high as that; but the results are fully warranted. We are finding today, that instead of the melting point of the brick being the deciding factor, it is the temperature at which it begins to compress; and it will begin to compress under a load of 40 to 50 lb. per sq. in. at 1800 to 2000 deg. fahr. Consequently, if combustion chambers are designed so that the load in the hot zone is not more than 25 lb. per sq. in. and so that the combustion chamber is inclined away from the grate, and if some means are provided to overcome the slight tendency for the brick work to fall into the center of the combustion chambers, there should be no trouble with combustion chambers, no matter how heavy loads are carried on the boilers.

JOSEPH J. NELIS. Mr. Myers has asked why there were no marine stokers. There are two serious limitations in the ship that do not exist in the shore plant.

The sea has not attracted the technical man as yet, and until it does, I do not think we shall get very far with improved machinery.

The second limitation is the space available. A ship is primarily a floating freight. Under the marine classification rules we have certain space allowed for machinery. If we exceed that it damages the registered tonnage and we are penalized by harbor dues, tonnage taxes and other operating costs.

The present marine boiler, in the freight boat particularly, is the Scotch boiler with internal furnaces. It fits the space conditions and is almost fool-proof. This boiler violates all the laws of furnace volume that stationary engineers have been developing through a number of years. A number of very scientific tests made by the Bureau of Mines and the Shipping Board have shown that with practically one-quarter of the volume used in furnaces of stationary boilers, the Scotch boiler gives over 80 per cent efficiency. This boiler has been adapted for marine service because it was found to be the best boiler and it is passing not because it is not the best boiler, but because of increase of steam pressures.

Stokers have been tried on the Scotch boiler, principally underfeed type. They would burn the coal without difficulty but they could not get rid of the clinkers, so they were finally abandoned.

Some of the large freighters tried chain grates years ago, and they worked fairly well on them. At one time I went round from the east to the west coast on a ship, four of whose boilers were fitted with chain grates. Leaving New York we took the ordinary bunker coal, Pocohantas, and upon arrival at Chili, we took on some Chilian coal, which fused and ran through the grates. We finally threw the chain grates overboard and came into port hand-fired on all boilers.

The marine man has one thing in his favor; that is an absolutely steady load factor.

There are a great number of water-tube boilers afloat now and there are a great many Diesel engines being used. If the stoker manufacturer will coöperate more fully with the marine boiler maker, there is a chance now to put in stokers on ships, as water-tube boilers are being adopted and they have the necessary furnace volume required to make marine stokers successful.

Lester C. Bosler. The coal operator today thinks that the specifications as laid down by the users of the small sizes of anthracite are rather severe. He is called on to produce $\frac{3}{32}$ barley in one case and $\frac{1}{16}$ barley in another, and if the $\frac{3}{32}$ barley is supplied practically all the undersize goes to waste.

We think there should be a reduction in the number of sizes. We would like to elminate the rice and barley as two sizes and combine them into one size, known as "boiler," which would mean a coal through a $\frac{1}{4}$-in. round mesh and over $\frac{1}{16}$-in. round mesh. We would prefer to make this through $\frac{1}{4}$ and over $\frac{1}{32}$-in.

The stoker manufacturers today say this is not an efficient fuel, but we think the time is coming, in order to increase the supply of these sizes, that an endeavor should be made to design a stoker furnace to burn the combination of what is now known as rice and barley.

At the present time we are shipping about 3,000,000 tons of barley every year, and if we could include a little more of the undersize we could probably increase this to nearly 4,000,000 tons, and if we can include the rice in with the new size known as "boiler," the total would be about 8,500,000 tons. All the above will, in turn, increase the amount of business that a stoker of this type could handle.

A. D. White. Previous to five years ago, I had no experience in burning anthracite coals. At the present time, in our plant, there are ten units, three feet wide and 40 feet long, in which anthracite coal is burned successfully. The coal runs anywhere from 38 per cent ash down to 14, and B.t.u. from 7500 up to 11,000. Usually with a shipment of bad coal, we have a hard time until we get rid of it. We run the boilers at about 160 or 180 per cent of rating, burning anthracite rice coal.

R. Sanford Riley. Mr. Myers has asked a few questions and we have tried to answer them. He spoke of fusion on the fuel surface of the underfeed stoker, because of the fuel working upward to the higher temperature zone. All I can say on behalf of the underfeed stoker is that it has no monopoly on the manufacture of clinkers.

Clinkers are the logical result of thoroughly burned-out ash, if the ash has the proper chemical elements. Silica, of course, makes glass and clinkers. Now, as to the troubles encountered in underfeed stokers from these clinkers, which are inherent in certain kinds of coal. I wish to avoid arches because of the reverberatory action under an arch, which raises the temperature, and makes the clinkers still more liquid. Of course manufacturers of chain grates claim that the clinkers which are made do no harm, because they are carried over. That would be ideal if there were no other limitations on the chain-grate stoker. In general the elimination of the arch allows the utilization of the maximum amount of radiation, using radiation as the means of transferring heat from the fuel bed to the boiler. That means cooler fuel bed, less trouble with brick work, and higher efficiency, and of course, less trouble with clinkers.

Mr. Myers also touched on the use of stokers at sea. There are the limitations of space. No doubt we will go, as Mr. Nelis says, to the raising of water tube boilers, because I think that is about the only reasonable possibility. The small combustion chamber in a Scotch boiler is a pretty hard proposition for stokers.

Mr. Myers asked about automatic regulation. I would like to say for one, that we hope that automatic regulation will come in. The difficulty heretofore has been that we have trouble enough to get operators with intelligence enough to regulate the fire directly. Now, when you want them to go one step further, and have intelligence enough to regulate a regulator, we have not quite come to that. I think the time is coming before long when the regulators will be much more generally used, and that is equivalent to saying that we are getting more intelligent fire-room operators.

Mr. Myers also raised a question regarding setting heights. We did the best we could with the Stokers Manufacturers' Association to establish a rule of thumb that we think good so far as it goes. We do not claim that is perfect, but it is certainly a great advantage to engineers to have some standard established by which some of the most serious mistakes can be avoided.

The point has been made that the stoker is the basis on which boilers should be selected. I believe that is true. The energy is liberated in the furnace. We all agree on that, so that is the starting point in any plant.

W. J. Wohlenberg. Much has been said about automatic control but no very definite idea of the mechanical process that goes on which makes it a definite part of the equipment has been given.

Consider a case of parallel operation, a number of boilers fed, say, by stokers, and having fans operating in parallel. The device which first responds to the load would be one which would change with the change of pressure. This device would operate on a throttle valve, or an electric control which governs, say, the fan. This fan drives the air through the fuel bed.

If a similar change is desired in all parts of the equipment every part of the system must have similar characteristics. That is, all the throttle valves, all the pressure devices and the fans, and even then the right condition will obtain only providing there is the same kind of fuel bed with the same kind of fuel under every boiler. This makes automatic parallel operation very difficult. It seems to me that the people who manufacture automatic control equipment would convey the right impression if instead of calling such equipment automatic control devices they would refer to them as aids in the control of combustion.

H. O. Pond. A stoker might be defined as a mechanical means of introducing fuel into the combustion space. With that thought in mind and to answer the question about burning 75 varieties of fuel, this can be accomplished by pulverizing the fuel.

R. H. Beaumont. When the problem of coal and ash handling comes to us we ask what kind of a stoker is going to be installed, and the owner frequently does not know. The solution of the problem must stop there and await the determination of the type of stoker. Then we make an attempt at solving the problem of properly preparing the coal, of putting it on to the stoker, and of storing, cooling, removing and ultimately disposing of the ashes produced by the stoker. We are handicapped because once having delivered the coal to the stoker, crushed to the proper size, we must take the ashes in the manner in which they are delivered.

The stoker is only one link in the chain and the problem of supplying coal to it and removing ash from it should be solved by coöperation between designers of stokers and coal- and ash-handling equipment.

W. G. Freer said that he was familiar with the Eldon stoker which had been used on locomotives and he felt that it could be adapted to marine boilers. The stoker scattered the coal over the grate.

T. A. Marsh. In all discussions of stoker, or combustion performance, we must keep in mind the ultimate goal — cheap steam production. Sometimes this is accompanied by high boiler and stoker efficiency and sometimes, as in the case where cheap low-grade fuel is burned, by lower efficiency. Investment charges, operating charges, maintenance and ability to burn low-grade cheap coal, are factors in cheap steam costs just as truly as is the efficiency of performance.

Automatic control of air and fuel has received considerable comment in this discussion. From present designs and existing installations it is evident that automatic control of firing operations is making rapid headway. It is the next logical advance step in boiler room operation. No control can be so automatic as to eliminate all manual attention. An ideal situation is automatic control with expert supervision.

Mr. Maynz has inquired regarding the tightness of the compartments of forced-draft traveling grates, — the early troubles of some of such stokers have been practically overcome, so much so that with these stokers, as constructed today, the leakage from compartments is negligible.

Answering Mr. Cary's suggestion as to a different combustion rate unit, I really do not see the purpose of describing the combustion performance by stating the amount of one constituent of the fuel that has been burned, neglecting all others. Sometimes it is much more to the credit of the stoker and furnace that the volatile, rather than the fixed carbon constituent, was consumed.

Actual coal is convenient for figuring capacities of steam output as coal analyses are reported on this basis, also, and not on the basis of fixed carbon.

All the fuel rests on the grate at the beginning of the combustion process. In turn each constituent re-acts in its own manner as subjected to furnace temperatures. Fixed carbon is the last to leave the grate, and its combustion in final analyses is a reaction of gases.

Mr. Cary asked regarding coking coals, — coking coals are unsuitable for chain grates.

The question of anthracite sizes and the modification of existing standards requires a lot of thought and study. Mine equipment for producing, as well as power plant equipment for burning, are both affected.

George I. Bouton. I agree fully with Mr. Cary's statement that it is desirable to eliminate " rousting " and hand-manipulation of overfeed stokers. The way to do this is to provide sufficient draft, and when a plant has out-grown the draft equipment, revise the draft equipment, instead of attempting to substitute a man at the end of a roust bar.

A number of those discussing this group of papers seem to be of the opinion that automatic control is desirable. There is no objection to automatic control where it is properly designed, manufactured, installed and operated. Up to the present time, I have not seen automatic control equipment applied to natural draft stokers which would meet those requirements.

H. F. Lawrence. First, I would like to state that the mechanical stoker is more than a coal feeding mechanism. In addition to putting the coal into the furnace, it must deposit the ashes into some locality from which they can be easily removed, and also furnish the air at such places and velocities and directions to accomplish the burning of the fuel in the best manner.

The underfeed stoker, of course, forms its ash on top. It is the feeding of the coal from the retort that floats the ash on the fuel bed. The coal in addition to rising up, is pushed forward so that the ash is carried forward toward the bridge wall with the fuel.

The underfeed stoker will burn a wide variety of coal. It is built with adjustments, the principal adjustments being the control of the coal from the retorts. That is what makes it possible to burn a wide variety of coals on the underfeed stoker.

We of course must accept the coal as it comes and burn the coal as we get it. Some coals are much worse than others for throwing off cinders. If it is light and friable, as it burns, it does not mat together and that makes more cinders than other coals. Higher setting heights are reducing the cinders.

The use of lower air pressures and velocities as the design is improved will also reduce the quantity of cinders.

High settings are reducing the slag on the tubes. With some fuels this slag is much worse than with others, and provision should always be made in the boiler setting to get at the slag to remove it.