metal, which it would have been far too costly, if indeed possible, to deal with by manual power.

It will thus be seen that all the circumstances in connection with steel manufacture favour the making and rolling of masses as large as can be used, and the greater the weight of the piece to be rolled, the greater is the necessity of supplementing manual labour by mechancial appliances; to this fact are due the numerous alterations which have evolved the mill of to-day, from its direct ancestor, the mill employed by Cort. What these alterations are will be explained in these pages, and if speeds, weights, dimensions, and outputs appear to be unduly dwelt upon, it must be remembered that the subject can only be adequately explained by giving working particulars of this nature.

The method of producing the raw steel has caused a continuous growth in the size and weight of the ingot, requiring corresponding increases in the sizes of the mills needed to handle the larger masses, the weights of which have continuously required more and more mechanical appliances to manipulate them, as they have either got altogether beyond the power of any number of men to handle properly or the cost of the extra labour involved has become prohibitive. The steady growth in the first cost of the mill and its appurtenances, has necessitated higher speeds, to obtain such an output as will give a satisfactory return on the capital expended, the whole stimulated by the continuous demand for reduction in the cost of the finished steel, under the pressure of ever-increasing competition in the trade.

Though these changes are the result of steady growth, the developments have occurred with such rapidity that few, if any, works are to be found, which are provided with all the best appliances in every department. Many old works cannot find room for modern appliances, and the output of otherwise fine plants is often restricted by some weak link in the chain.

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REHEATING.

By J. W. HALL.

CHAPTER XXI.

REHEATING FURNACES.

Coal-fired Furnaces.—Before steel ingots can be worked by the hammer or press, they must be heated sufficiently to render them soft and malleable, and for this purpose, Bessemer naturally employed the furnaces he found in use for heating iron piles. These furnaces were constructed as shown in figs. 292 and 293, in which A is the fire grate, B the fire-bridge, C the hearth on which the material to be heated rested, and D the flue leading to the chimney, E. The floor of the furnace, made of gravel covered with sand, sloped towards the chimney, to enable the slag formed by the Oxide from the surface of the hot metal, combined with some of the melted sand of the hearth, to flow to the slag hole, F, where it ran off through the spout, G, a small fire being usually necessary at the hole, to maintain the slag in a fluid condition. This slag, known as "flue cinder," is sold for use in blast furnaces, where the iron contained in it is recovered by being reduced to the metallic state, in the presence of incandescent coke. The fuel is introduced through the door, H, and the metal to be heated through the doors, I I, while K is the damper placed on the top of the chimney, where it may be kept comparatively cool by the air above it, the fire being regulated by raising or lowering the damper by means of the rod, L.

Such furnaces are open to grave objections. In the first place they can only be worked efficiently with coals containing sufficient Hydrocarbons to give a long luminous flame, and enough Hydrogen to produce the requisite intensity of heat, and the ash must be low enough for the fires not to need frequent cleaning, whereby much heat is lost. The "Black Country" of South Staffordshire owed its pre-eminence in the iron trade, which it so early and so long enjoyed, almost entirely to the possession of a seam of coal of this description 10 yards thick, which was easily mined when modern means for deep mining were unknown; indeed in numerous places it actually cropped out of the surface of the ground.

The fires in these furnaces require careful attention. As the draught necessary for rapid combustion is obtained by the comparatively feeble vacuum created by the column of heated gases in the chimney, the fuel must be in large lumps to allow a free passage for the air sucked in through

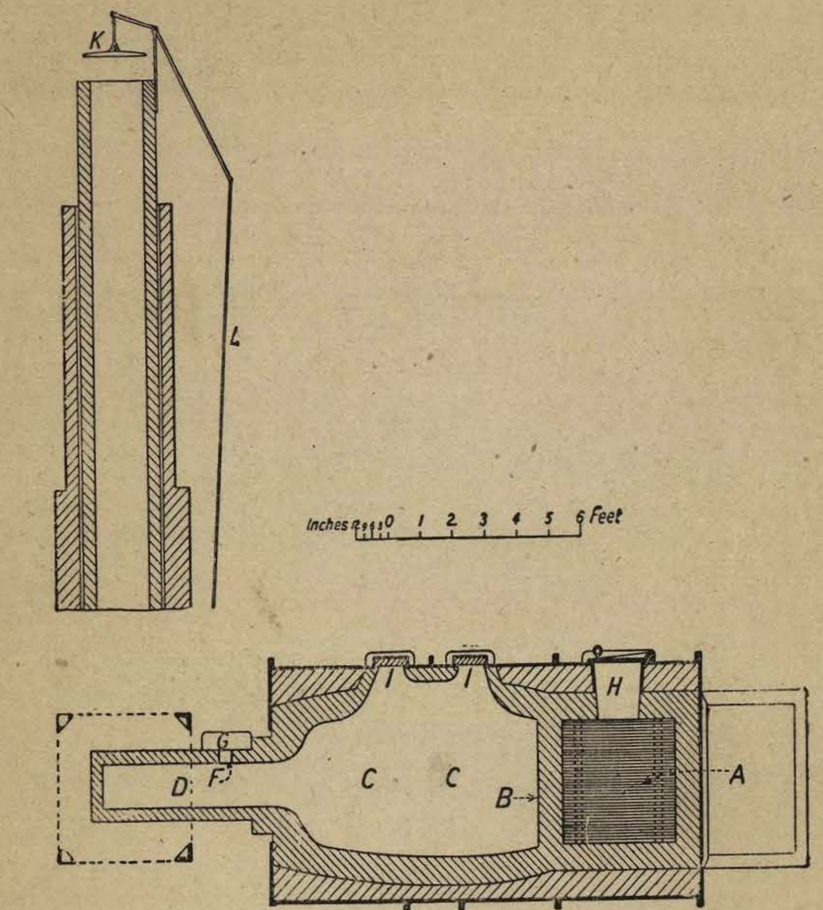


Fig. 292.

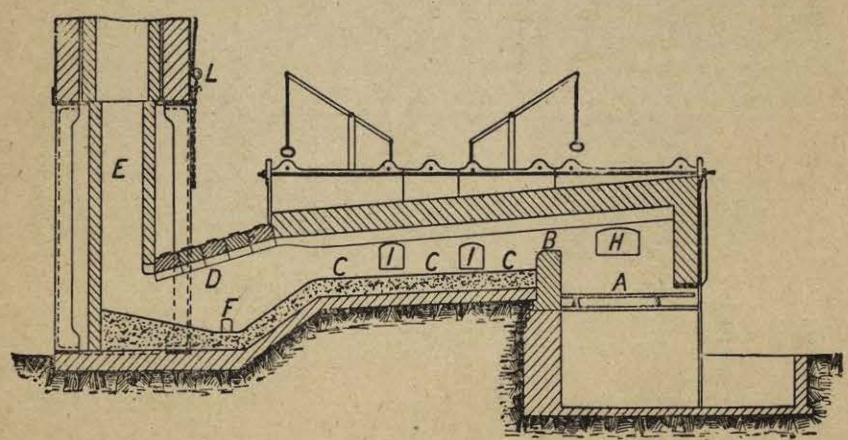


Fig. 293.—Old Form of Coal-fired Reheating Furnace.

the grate, and such large coal is expensive. The fire must be maintained at a very uniform thickness, for if too thick the volatile Hydrocarbons in the coal are merely distilled off, and pass away in the form of volumes of dense black smoke, which, if sufficiently heated, burns freely at the top of the chimney, where it meets with enough air to complete its combustion. The rapid burning of the coal, however, soon causes the fire to get so thin that much more air passes through the grate than is required for combustion, often as much as 50 and even 100 per cent. in excess, when much of the available heating power of the fuel is absorbed in raising this surplus air to the temperature of the furnace. If the firing door is opened to put on more coal, large volumes of cold air rush through the furnace, cooling it and its contents; while the additional fuel, until thoroughly lighted, lowers the temperature of the grate, and, of course, of the furnace.

The fire is consequently subject to considerable and frequent fluctuations of temperature, and therefore cannot be kept at its highest efficiency for long together. If a welding heat is required the material must first be raised to a high temperature, and the fire brought to its best condition, all doors shut as closely as possible, and the damper opened to urge the fire. The piles are then drawn one after the other at a "dripping heat," and rolled off as fast as possible; and when the "round" is completed, the furnace is re-charged and the process repeated.

So much of the heat in such furnaces is generated in the fireplace, where it is not wanted, and so much of it expended before reaching the flue, that the piles next the bridge may be "scorched" or "blistered" by the oxidising action of the flame, before those at the other end of the furnace are hot enough to roll, so that the latter frequently require to be moved up to the bridge after the others have been drawn, the excess of air admitted through the open door, while this is being done, "cutting" the piles and causing excessive waste.

When cold ingots were charged into such a furnace, at least 10 to 12 cwts. of large coal were consumed per ton of steel heated, and the waste by oxidation in the furnace was 7 per cent. and over.

Slack-fired Furnaces.—A great improvement was effected about 1875-80 by the addition of a forced draught below the grate, whereby the rapidity of combustion was no longer limited by the draught afforded by the chimney. This forced draught was produced by jets of steam, which injected air into a closed ashpit, situated below the fire-bars. Only one-fifth of the air can form a combustible gas with the incandescent fuel, because the other four-fifths is inert Nitrogen; this not only dilutes the active gas, but has to be raised to the same temperature as the other when burnt, and therefore absorbs part of the heat which the other gives out, thus reducing the possible temperature of combustion, and carrying the heat it thus acquires up the chimney. On the other hand, if the steam is not excessive, and the bed of incandescent Carbon sufficiently thick, all the steam is decomposed into combustible gases. The greater the proportion of Carbon which combines in this way with steam, the less Nitrogen has to be uselessly heated up. The reaction absorbs a considerable amount of heat at the bottom of the fire, thus protecting the fire-bars, which heat is given out again, when the Hydrogen is burned by air admitted for the purpose at the bridge, the steam thus acting as a convenient carrier of heat, from a place where it is not wanted, to the one where it is most useful.

The use of the forced draught enabled the density of the fire to be considerably increased, whereby slack fuel could be used, costing only from one-half to two-thirds as much per ton as the large coal formerly employed and the amount of the draught being under control, the thickness of the fire could vary within much wider limits, without affecting the economy, or the temperature obtainable.

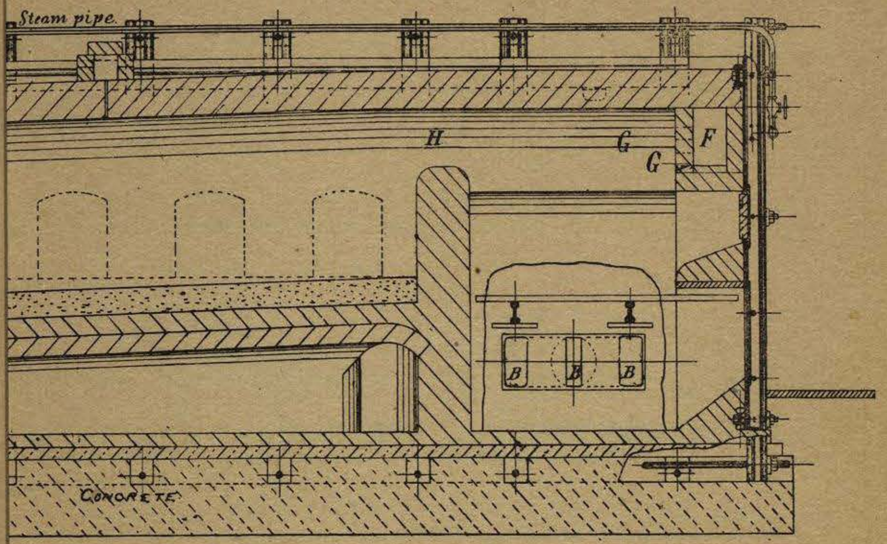
Figs. 294 and 295, Plate xxii., show a recent furnace of this kind at work in some English works, in which the secondary air, which must be supplied above the grate when a deep bed of fuel is kept, is subjected to some preliminary heating. The primary air is driven by the steam jet blowers, A, A, and issues through the openings, B, B, B, which are arranged as shown, so as to evenly distribute the air pressure below the grate, and thus avoid an excess of pressure in one spot, which would cause cavities in the fire through which cold air would pass. The air thus supplied burns the fuel partly to Carbon Monoxide, and partly to Carbon Dioxide, and to enable the nature of the flame to be controlled the secondary air supply is provided. This is afforded by the blowers C^1 and C^2, which deliver air to the winding passages D^1 and D^2 beneath the furnace hearth, whereby the air is warmed. The air from D^1 passes up through the passage E, along the side of the firegrate into the passage F, and that from D^2 up the passage E^2 also into the passage F, from which the heated air issues in fine streams through the openings, G. There it meets the products of more or less complete combustion from the grate, and mixing with them consumes any excess of Carbon Monoxide formed on the grate, which thus forms a species of gas producer, delivering an intensely hot flame over the bridge, H, into the body of the furnace. By regulating the blowers C^1 and C^2, a flame is obtainable which has little oxidising effect on the metal heated, and yet allows little Carbon Monoxide to pass away unconsumed.

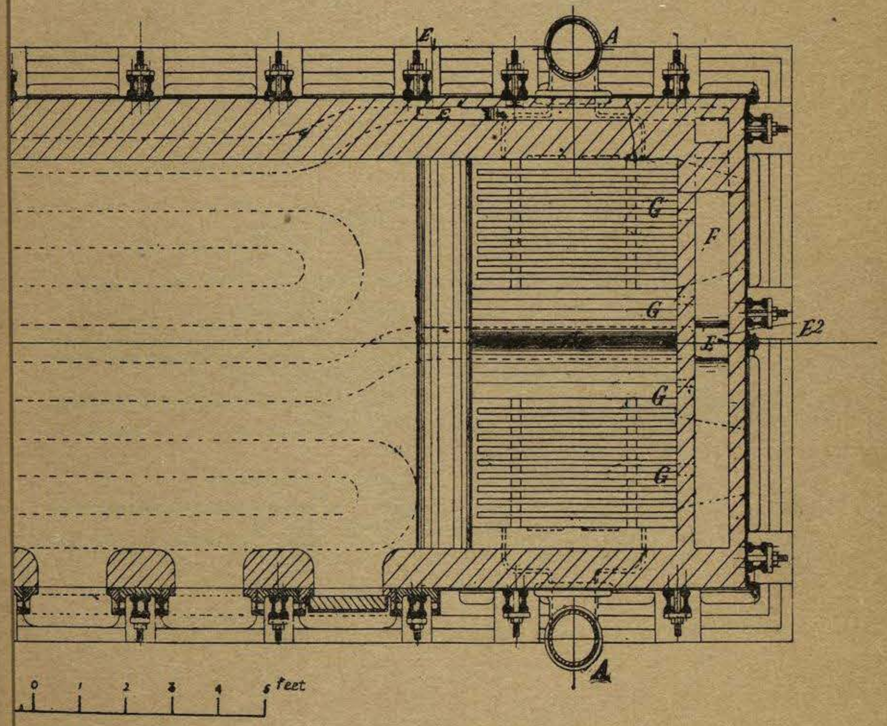
Furnaces of this construction reduce the consumption of fuel to 9 or 10 cwts. of slack per ton of ingots charged cold, or to 7 or 8 cwts. if they are charged hot, and the furnace waste in the latter case runs, as a rule, from 4 to 5 per cent.

The Moor Furnace.—This furnace (figs. 296, 297, 298, and 299, Plate xxiii.), which has been in use for some years at the Moor Steel and Iron Company's Works, near Stockton, for heating plate slabs, is the invention of Mr. C. J. Bagley, the general manager of the works. It is fired with slack and a forced draught, and has a removable lid on the top, which is lifted to admit the slabs, which, by means of a pair of tongs hung from a crane, are charged in pairs, one above the other, with bricks between them. The lower slab rests on supports in the furnace, and as the heat is free to play between, above, and below the slabs, a very uniform heat is obtained; as two slabs only occupy the space taken by one in most furnaces, floor space and first cost of furnaces are economised. Being small and sunk below ground, radiation is reduced, and the furnace is claimed to be economical in fuel, while it certainly occupies little space and is easily charged. This system of removable lid is often employed for close annealing furnaces in America and on the Continent, but in this country the annealing pans are usually rolled in on cannon balls.

Raising Steam with Waste Heat.—Seeing that the temperature over the whole of the bed of the furnace must be very high, or the material furthest from the fire is insufficiently heated, the products of combustion necessarily leave the flue at an excessively high temperature, and carry away with them more than half of the whole heating power of the fuel. If a hole be made in the side of the chimney, it will be found to be at a bright red heat inside almost to the top. Now although the vacuum created by a column of heated air, increases directly with the increase in its temperature above the external air, nevertheless, its power of drawing in air through the grate does not increase indefinitely, because the increase in *volume*, due to the rise in temperature, reduces the *weight* of the gas which the chimney can dis-

. 294.—*Elevation.*





. 295.—*Plan.*

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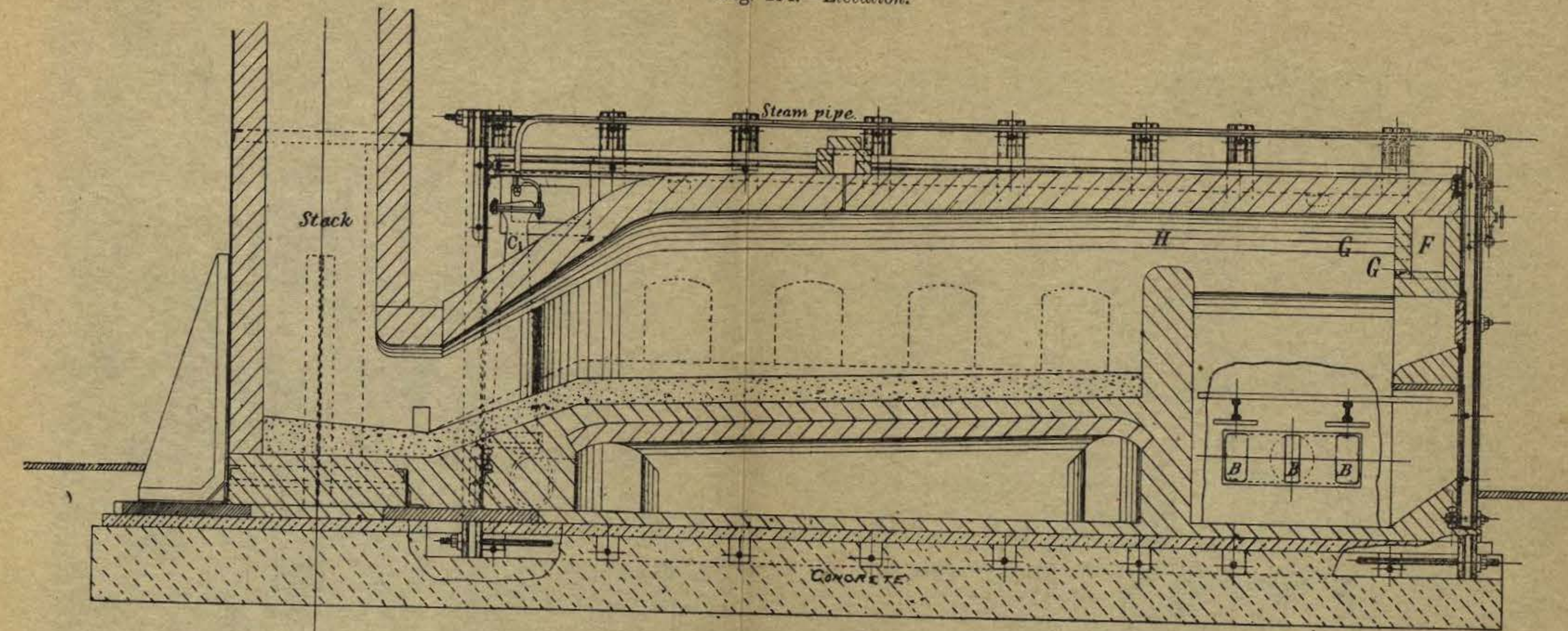
PLATE XXII.—Reheating Furnace with Forced Draught.

Fig. 294.—*Elevation.*



A A, Steam jet injection blower.
B B B, Openings for distributing air under grate.
C_1 C_2, Subsidiary injection blowers.
D_1 D_2, Passages through which air from C_1 C_2 passes.
E E_2, Passages through which hot air from D_1 D_2 is delivered into F.
G G, Small openings through which air from F passes over the top of fire grate.
H, Fire bridge.

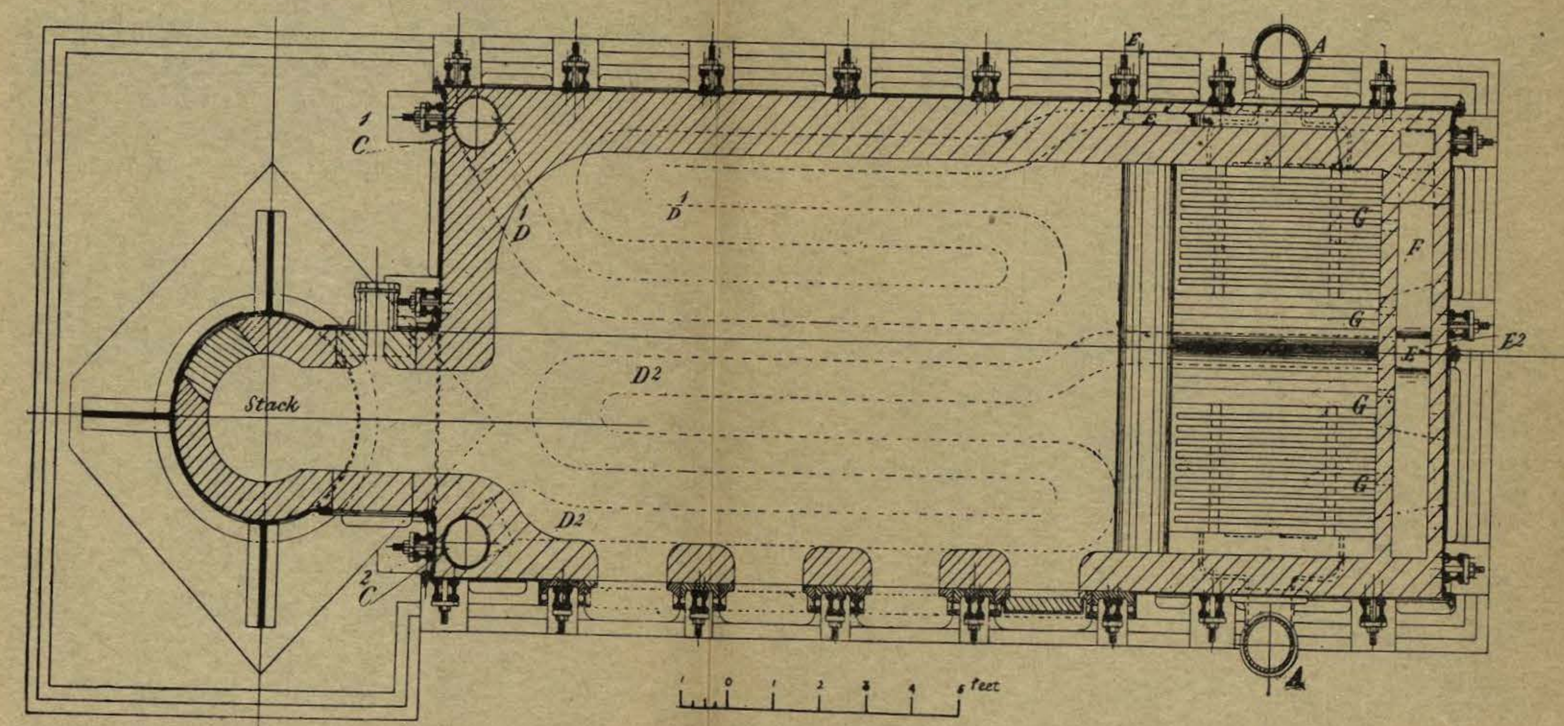


Fig. 295.—*Plan.*

ating Furnace.

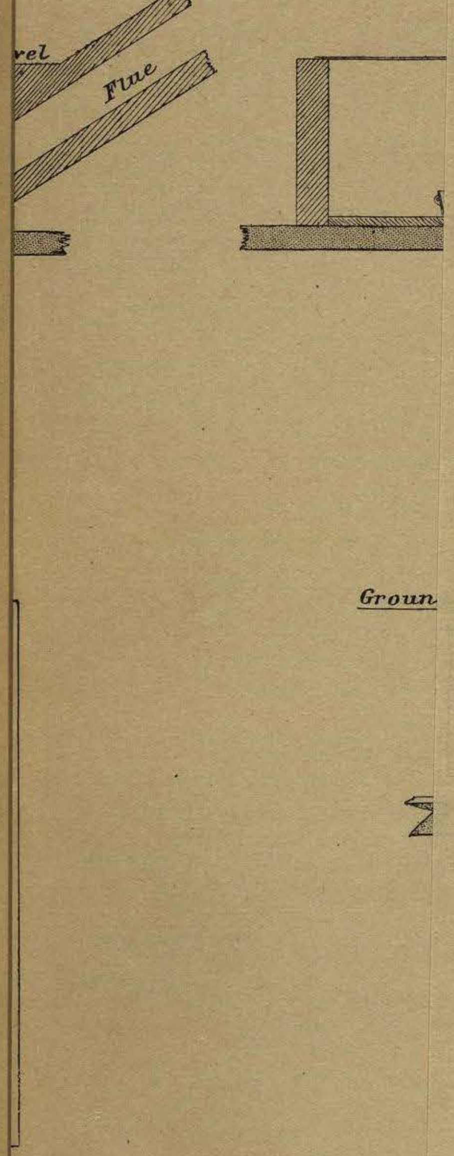


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PLATE XXIII.—Bagley Patent Slab Reheating Furnace.

D, Fire grate.
L L, Slabs separated by bricks in furnace.
M M, Slabs being charged into furnace.
a, *a*, Steam jet injector blowers.
S S, Cinder pots.

The furnace is sunk beneath the ground level, and the slabs are charged in pairs as shown, separated by bricks.

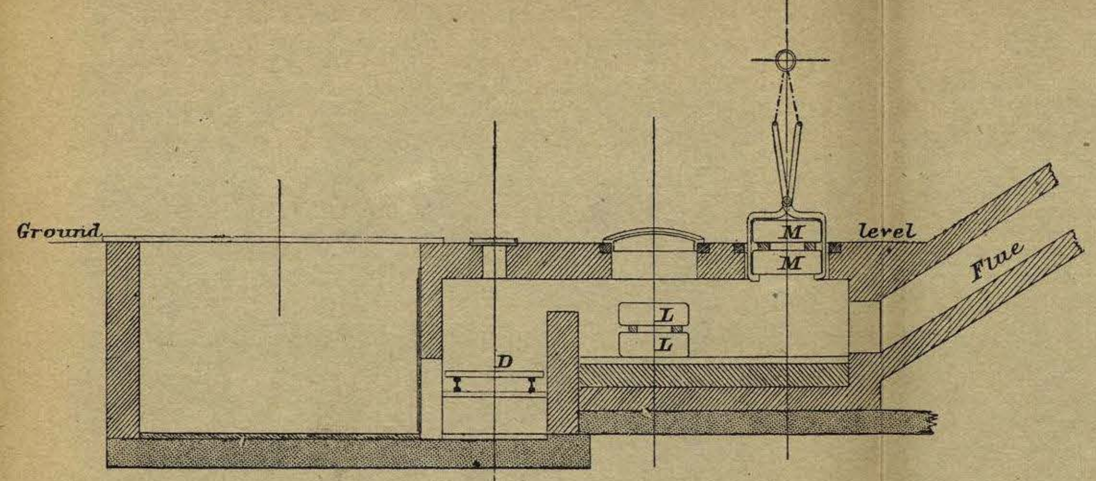


Fig. 296.—*Sectional Elevation.*

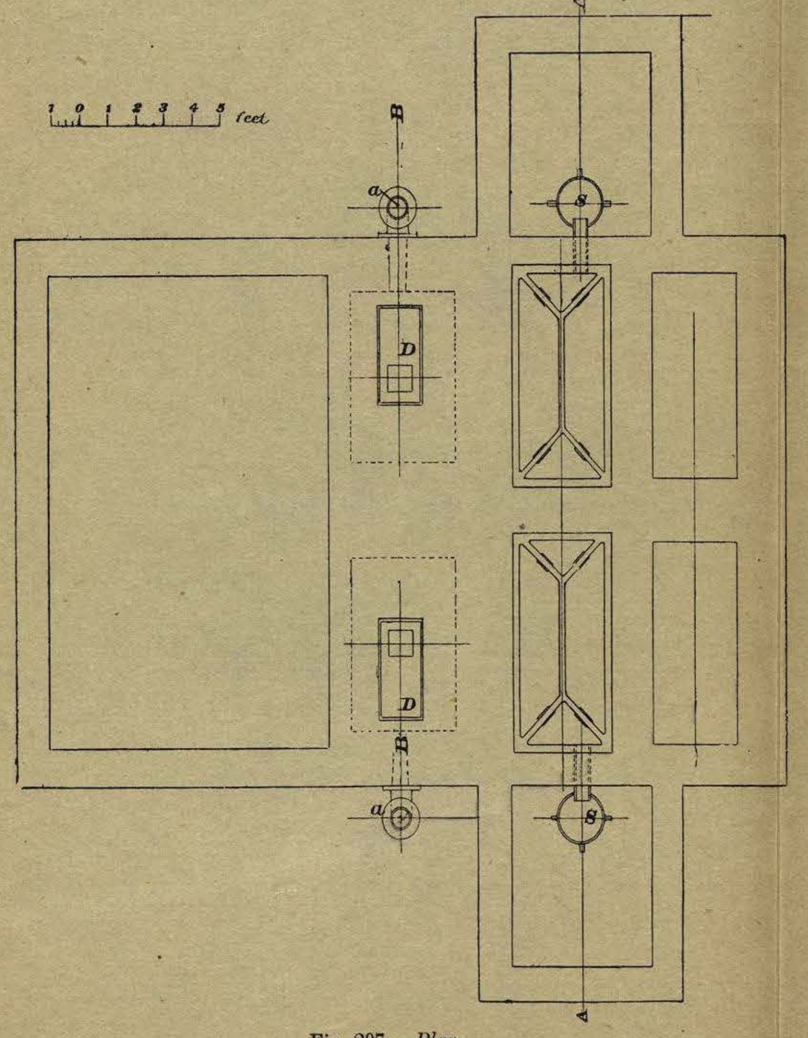


Fig. 297.—*Plan.*

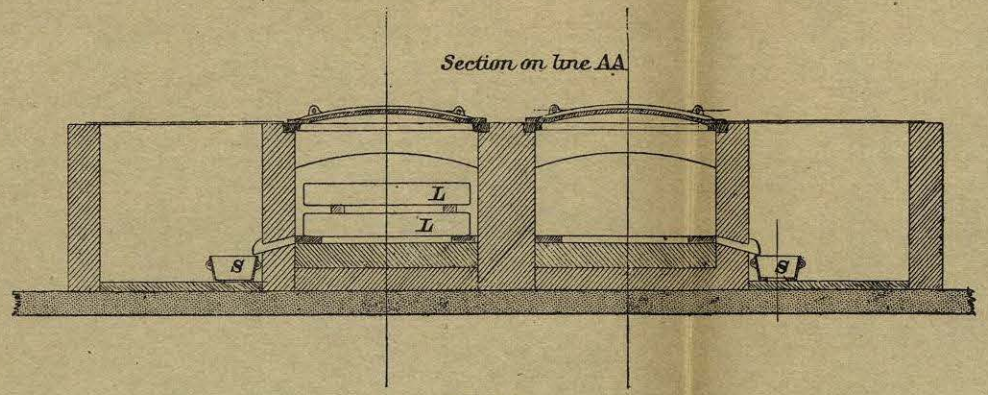


Fig. 298.

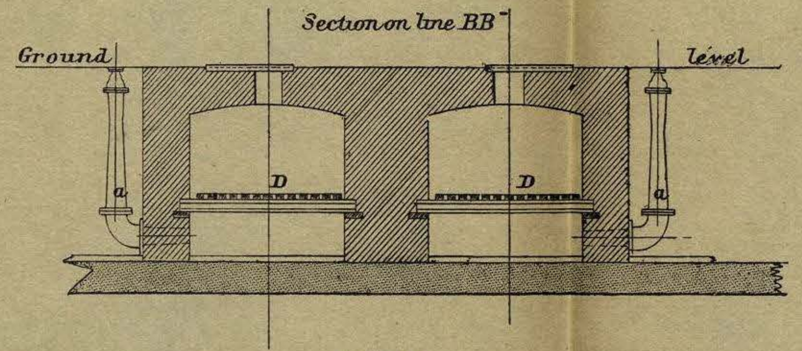


Fig. 299.

charge in a given time. According to Péclet, the maximum discharge is obtained when the temperature in the chimney reaches 525° F., beyond which point there is a slow diminution in effect. Owing to friction in the flues, probably 600° to 700° F. is nearer the best heat in actual practice.

The efficient working of the furnace is, therefore, not impaired by the addition, between the furnace and the chimney, of boilers, under, through, or around which the products of combustion may play, and give up their superfluous heat to the water contained in the boiler. By this means each pound of coal burned on the grate, while heating the ingots, evaporates, by its waste heat, $2\frac{1}{2}$ to $3\frac{1}{2}$ lbs. of water, which steam is available for driving the mill engines.

As this steam would otherwise have to be provided by slack burned under "hand-fired" boilers, in which it would evaporate from 5 to 7 lbs. of water per lb. of slack (if the boilers were fitted with economisers and every other refinement it might evaporate as much as 8 lbs.), it is only fair to deduct from the gross fuel burned at the furnace the proportion which would have to be burned elsewhere if the waste heat were not thus available for the purpose. Regarded in this light, the net fuel expended in actually heating a ton of ingots charged hot into a slack-fired furnace fitted with a boiler, is only from $3\frac{1}{2}$ to $4\frac{1}{2}$ cwts.

Figs. 300 and 301 show a reheating furnace fired with slack, recently erected at works in Great Britain. The draught is forced by a steam jet (not shown in the drawing), and the furnace is provided with a Babcock & Wilcox patent water-tube boiler, for absorbing the waste heat contained in the products of combustion. The following are some results obtained with similar furnaces and boilers :—

TESTS OF BABCOCK & WILCOX'S BOILERS WORKED WITH WASTE HEAT FROM COAL-FIRED FURNACES.

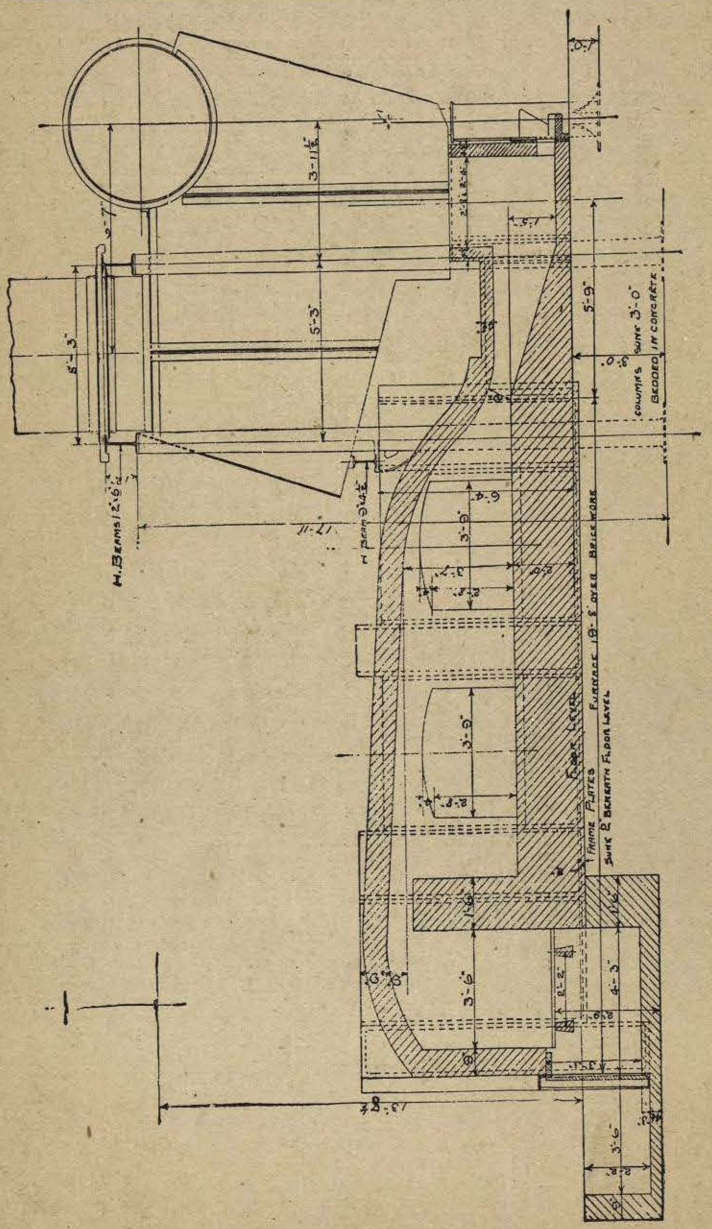
Test No.	Duration of Test.	Class of Fuel.	Lbs. of Water Evaporated.	Lbs. of Water Evaporated per lb of Fuel Steam and Feed, 100 C.	Consumption of Coal per ton of Steel Heated, after Deducting Coal used for Raising Steam at 6 lbs. Water per ton of Fuel.
1	12 hours.	Durham.	27,061	4·78	1·56 cwts.
2	,,	Scotch splint.	19,584	4·03	2·04 ,,
3	,,	,, single nuts.	30,523	4·30	3·37 ,,
4	,,	,, dross.	28,230	4·00	3·53 ,,
5	,,	,, splint.	47,940	5·69	...
6	,,	,, triping.	32,619	3·40	2·75 ,,
7	,,	,, ,,	24,360	3·20	2·25 ,,

In No. 5 the doors were clayed up, the furnace left empty, and fired for steam raising only.

The boiler had 600 superficial feet area of tubes.

Draught regulated in all cases so as to give 10 per cent. of Carbon Dioxide in the waste gases.

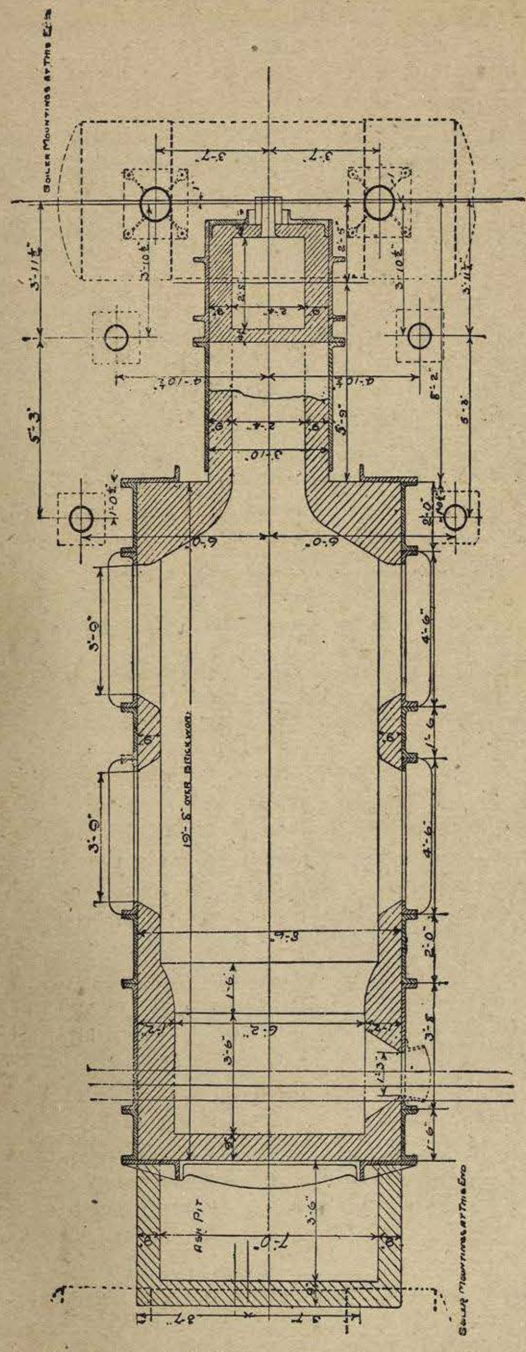
	Moisture.	Ash.	Volatile Matter, less Moisture.	Fixed Carbon.	Sulphur in Coke.	Total Sulphur.	Total Carbon.	Hydrogen.	Calorific Value by Calorimeter.
1	0·86	6·96	29·94	62·24	0·027	0·739	81·09	5·34	8,250
2	5·86	4·30	33·58	56·26	0·142	0·767	72·09	5·12	7,140
3	7·80	11·92	37·26	43·12	0·070	0·575	64·53	4·65	6,490
4	10·46	10·00	31·10	45·44	0·192	1·945	61·66	4·45	6,160
5	6·32	4·70	31·58	57·40	0·328	0·794	70·31	4·62	6,710
6 } 7 }	8·10	10·32	34·10	47·48	0·109	0·973	64·34	5·18	6,490



Sectional Elevation.

Fig. 300.—Elevation of Reheating Furnace, with Babcock & Wilcox Boiler attached.

Gas Furnaces.—The calorific power, or total heat, obtainable from fuel, may be fairly satisfactory, and yet its calorific intensity, or pyrometric effect, may be very low. A very high temperature, for instance, is readily obtainable



Plan.

Fig. 301. —Plan of Reheating Furnace, with Babcock & Wilcox Boiler attached.

in furnaces fired with good British coal or slack, capable of affording a long flame, but there are many districts on the Continent, where the only coals obtainable, though containing considerable heating power, will not give an-