at the throat of the furnace. Since the introduction of the hot blast, however, it has become usual to apply some arrangement

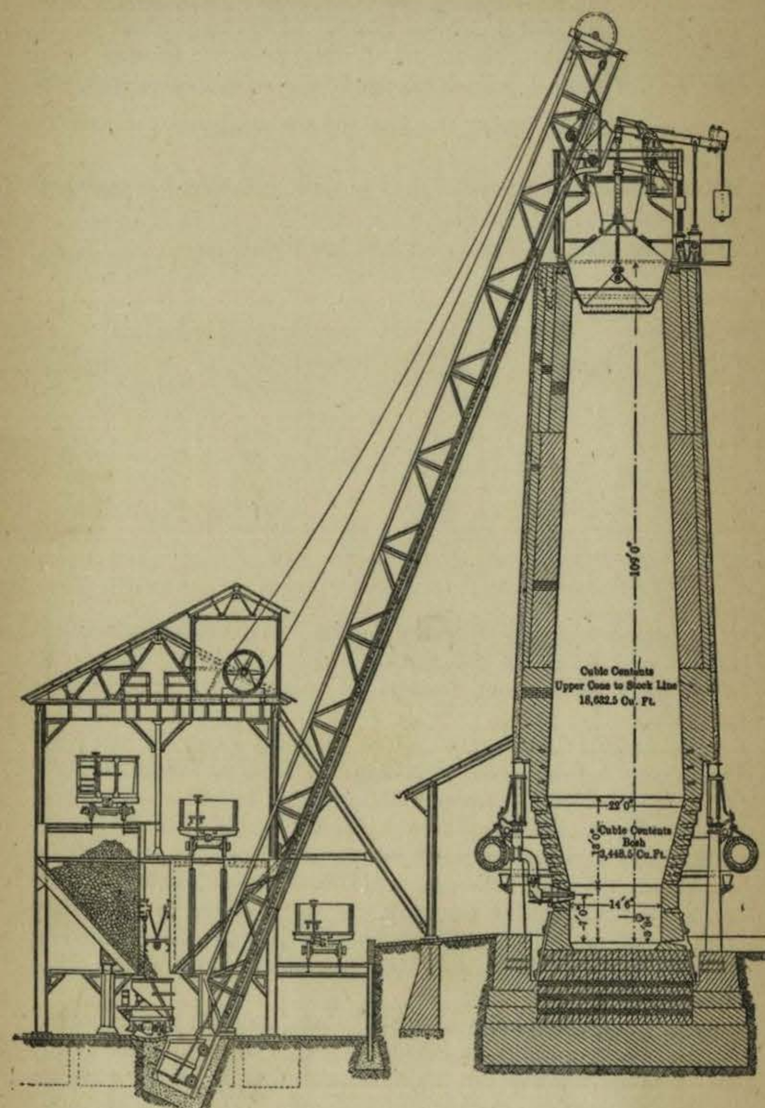


Fig. 152.

for closing the throat of the furnace and for collecting the waste gas. The *cup and cone* invented by Parry is the arrangement generally used. The throat is closed by an iron cup-shaped

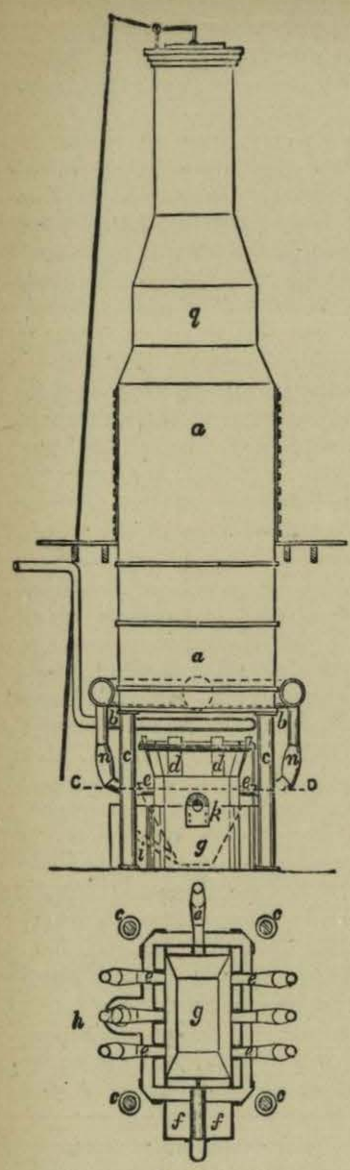
casting, the diameter of which at the lower end is about one-half of that of the throat of the furnace. Beneath this cup a cast-iron cone is suspended from its apex, and when the charge has descended from the cup which forms a hopper, the cone is raised so as to completely close the throat, and the gases pass out through a lateral pipe.

In Germany, arrangements are largely used by means of which the gases are withdrawn from the centre of the throat instead of from the sides. The apparatus of Langen and of Von Hoff afford good examples. In the former, the bell-shaped tube which closes the throat is raised, whilst in the latter it is lowered in order to allow the charge to fall into the furnace. In both cases, gas-tight joints are obtained by the aid of water-troughs. A double bell is now in general use, and this is seen in position in fig. 152.

Blast-furnaces are very largely used in the smelting of lead and copper ores, and the size and capacity of these furnaces have undergone a wonderful development during the last ten years.

With a view to produce a better distribution of heat, Truran proposed, in 1857, to increase the sectional area of the blast-furnace from the hearth to the throat. This plan was adopted by Raschette in 1862. His furnace in section is a narrow rectangle with six or eight tuyères on each side, placed so as not to be directly opposite. As the blast is distributed over a large section in the zone of fusion, the combustion in this furnace is perfect, and a large out-turn is possible. It is largely used for smelting lead and copper ores. The Raschette furnace used for smelting lead ores in the Upper Hartz is 20 feet high, 7 feet 6 inches long, 4 feet 10 inches wide at top, and 3 feet at bottom. There are five tuyères at each side, and, in the more recent furnaces, one at each end.

Rectangular furnaces of the Raschette type are largely used in Colorado for lead-smelting. The furnace is formed of two independent parts, the masonry stack, *a* (figs. 153 and 154), supported on a main cast-iron plate, *b*, resting on cast-iron pillars, *c*, and the crucible upon which rest the water-jackets. These constitute one of the greatest improvements ever introduced in the construction of blast-furnaces. They are hollow boxes, made of cast iron, malleable iron, or steel boiler-plate, in which water circulates freely, so that the temperature of this portion of the furnace-wall, where the most intense heat prevails in the interior, never exceeds 70°. The water-jacket arrangement is always sectional, so as to afford every facility for the removal of the jackets when the furnaces need important repairs. This arrangement must be highly commended, as it admits of the expansion and contraction of this portion of the furnace without altering the relative positions of the parts. The importance of this arrangement will be appreciated when it is



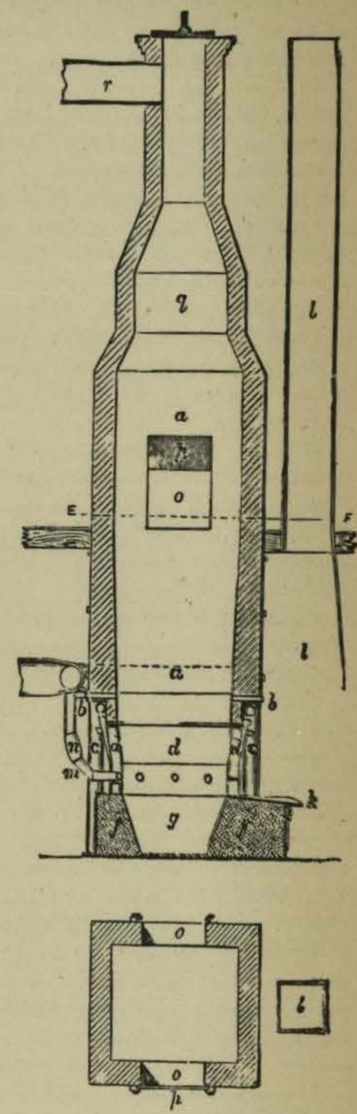


FIG. 153. FIG. 154.

Raschette Furnace.

stated that smelting campaigns of thirteen months are known at Leadville.

The Leadville rectangular furnace is shown in the accompanying figures, 153 and 154, which are drawn to a scale of 9 feet to the inch. The dimensions of the furnaces vary at the different works, as the daily smelting capacity varies from 15 to 40 tons. The water-jackets, *d*, are, in the furnace represented, twelve in number, bolted together and provided with openings for the tuyères, *e*. A cold-water pipe runs round the furnace, and supplies water to the water-jackets. The lower ends of the latter rest on the hearth, *f*, which consists of cast-iron plates lined with fire-bricks or brasque. The usual form of the bottom is shown at *g*. The hearth-plates enclose the lead-well, *h*, and the channel, *i*, through which the molten lead rises to the level that it occupies in the furnace, and can be ladled into moulds without interrupting the work. At the side of the furnace, an opening is left in the water-jacket for tapping off the slag, which runs down the gutter, *k*, when the clay stopping the aperture is pierced. A hood, *l*, is placed so as to carry off any fumes evolved during tapping. Cold blast is now practically always used, and the tuyères are connected to the blast-pipes by flexible canvas hose, *n*, and a slide, *m*, at the elbow of the nozzle, admits of looking into the interior of the furnace.

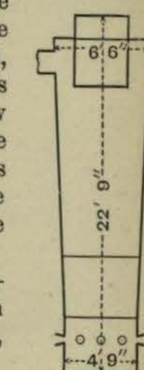


FIG. 155.

The feed openings, *o*, are closed by counterpoised doors, *p*, and the furnace terminates in a short chimney, *q*, communicating by a flue, *r*, with dust-chambers.

Blast-furnaces of the Pilz type, first introduced in 1875, are also used in Colorado; but the rectangular furnace of the Raschette type is generally preferred, as it is less expensive in construction. In Europe, on the other hand, the former has almost entirely superseded the latter. The Pilz furnace, which is generally employed for smelting mixed ores of lead and copper, is circular in section. Its internal profile, which is shown in fig. 155, differs from any of the types given in fig. 151. In this case $\frac{H}{D}$ is more than 3, but the widest part is at the top, the contraction being gradual to the "crucible" portion of the furnace in which the tuyères are placed. The actual area at the throat is, however, much restricted by a cylinder of wrought iron through which the charge is introduced. The appearance of the exterior of the furnace, as used at Freiberg, is shown in fig. 156.

Prof. Gowland,[1] in his presidential address before the Institu-

[1] *Trans. Inst. Min. and Met.*, vol. xvi., 1906–7, p. 265.

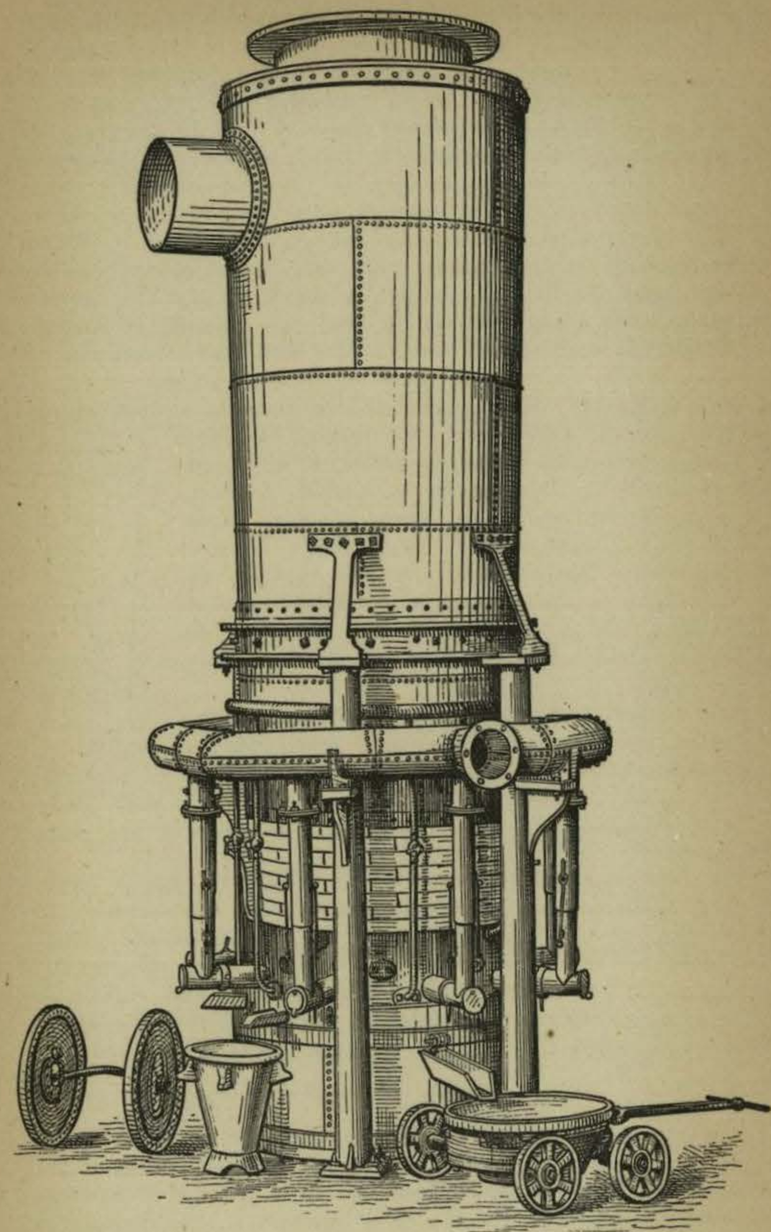


Fig. 156.—Pilz Furnace.

tion of Mining and Metallurgy, reviewed the chief advances in copper-smelting in modern times, and illustrated the gradual

development of the blast-furnace for copper-smelting during the

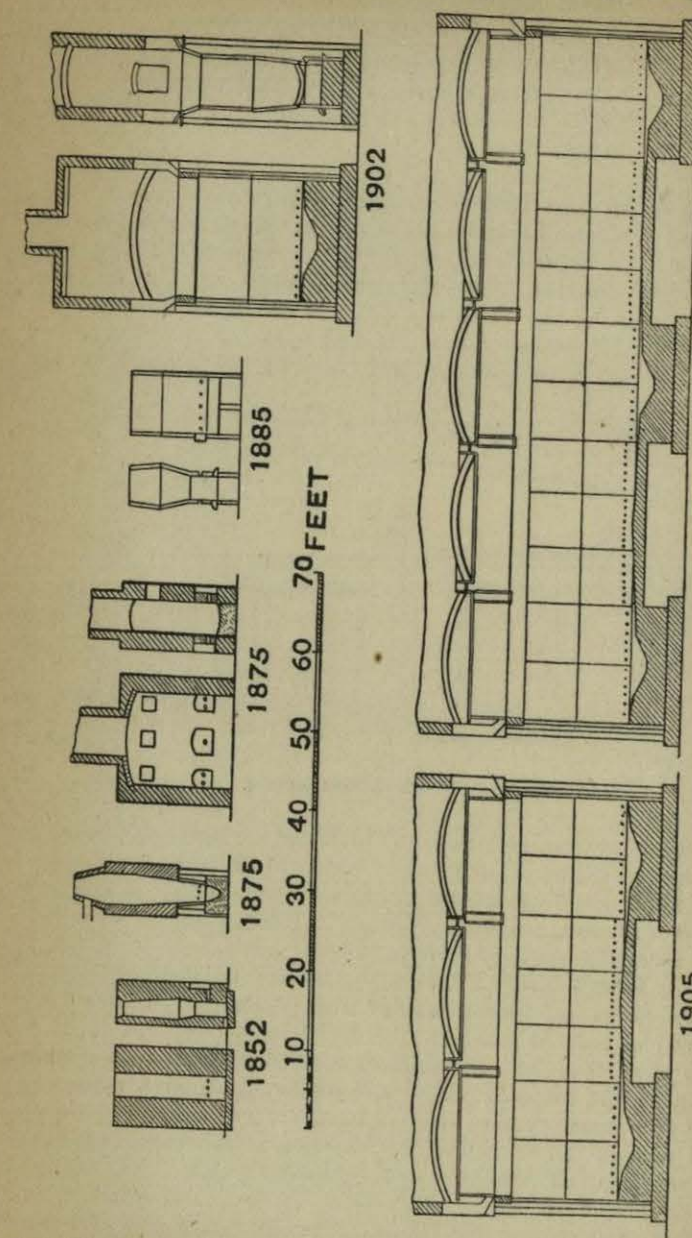


Fig. 157.—Development of the Copper-Blast Furnace.

last fifty years. Fig. 157 is taken from this address, and shows the following furnaces ;—

1852. Mansfeld Furnace.
1875. Pilz "
1875. Orford "
1885. Parrot Silver and Copper Co. Furnace.
1902. Washoe Furnace of the Anaconda Co.
1905. " " "
1906. " " "

Up to the year 1885 the largest copper blast-furnaces were only of small size, being 96 inches long by 36 inches wide, and up to 1902 the largest furnaces used were 120 inches by 42 inches. In 1902, however, a complete modification of furnaces was commenced by the Anaconda Co., by building a furnace 180 inches by 56 inches. Since this date immense leaps have been made by the same company, first in 1904, by joining up two

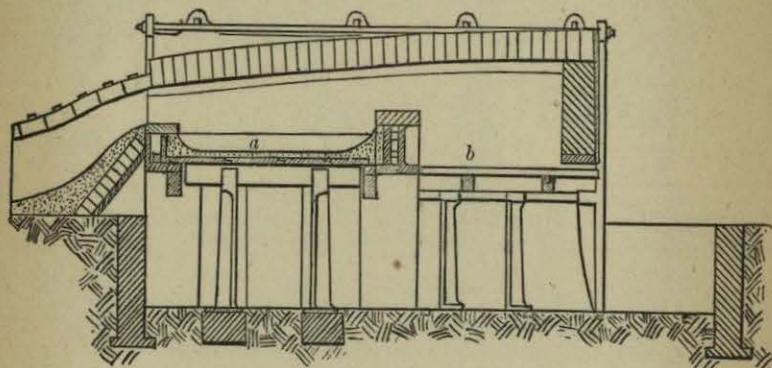


FIG. 158.—Puddling-Furnace.

adjacent furnaces, including the 21 feet space between, making a furnace of the total length of 52 feet. In 1905 another enlargement was made by joining up this 52 feet furnace to another 15 feet furnace, including a space of 21 feet, giving a furnace of the enormous length of 87 feet.

III. **Reverberatory Furnaces.**—These are constructed of very varied forms and dimensions, but their construction is guided by principles common to them all. Reference to figs. 158 and 159 will show that the reverberatory furnace consists of two main portions, the fireplace (either an ordinary grate or a producer) and the laboratory part, the fuel being separated from the ore, or the material to be heated, by means of a *fire-bridge*, which is simply a wall of refractory brick, usually furnished with an air-channel to keep it cool, and sometimes provided with orifices which admit air into the furnace. As the flames pass over this bridge and *reverberate* into the laboratory part, it will be evident that its height in relation to the position of the roof has to be

regulated with much care, for on it will depend whether the flames act directly or by radiation on the material to be heated.

The laboratory part is connected by means of a flue with a chimney, which serves for the withdrawal of the waste gases,

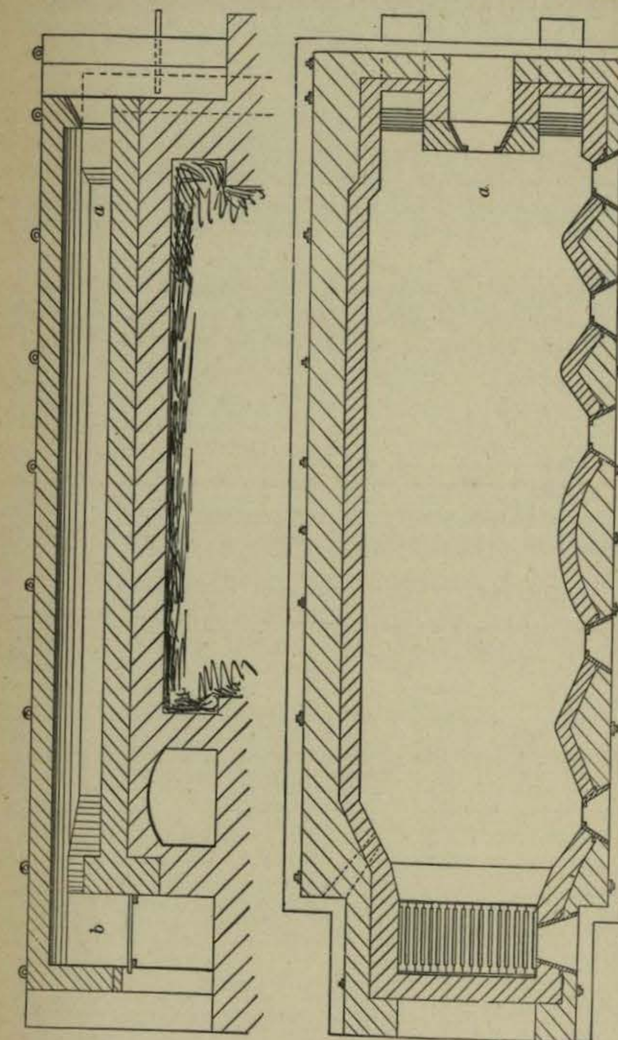


FIG. 159.—Roasting-Furnace.

and in many cases also for the production of draught. A damper at the base of the chimney or in the flue enables the current of air to be regulated; and, taken in connection with the thickness of the layer of fuel burnt on the fireplace, the atmosphere may be rendered oxidising, neutral, or reducing, at will. Figs. 158 and 159, exhibiting two extreme cases, show how much the dimensions of the laboratory part in relation to the fireplace may vary. In fig. 159 a more or less pulverulent material has to be kept comparatively cool at the end of the furnace furthest from the fireplace, *b*, and to be gradually advanced to the hottest part, which is, of course, in close proximity to the fireplace. On the other hand, in fig. 158, a puddling-furnace, the material, although energetically stirred, retains its original position on the bed, *a*, and has to be actually melted. In the former case the bed of the furnace is a plane, which may slope, but which is usually horizontal. In cases similar to the latter, in which the charge has to be wholly or partially melted, the bed is concave. The nature of the material of which the furnace-bed is composed is very varied. In cases where the temperature is not high, as in the calcination of lead ore, fire-bricks, which need not be very refractory, are used. In copper-smelting furnaces some 2 feet of siliceous sand is rammed tight. Brickwork is unsuitable for this purpose, as the regulus or copper resting on it works down through the joints. In Swansea the furnace-bottoms are made of a moderately refractory sand containing 88 per cent. of silica. In certain lead-smelting furnaces the working bottom of the furnace is made of the grey slag supplied by the furnace itself. The bed of the puddling-furnace introduced by Cort was made of sand. In 1818 iron plates covered with oxides were substituted for the sand bottom with great advantage.

EXAMPLES OF REVERBERATORY FURNACES.

	1. German Long-bedded Calciner.	2. Copper-furnace for Regulus, Washoe Plant, Anaconda Co., 1906.	3. Cwm Avon (S. Wales), Copper-furnaces (*Levy*).	4. Butte Copper-furnace for Matte, 1903.	5. Flowing Lead-furnace.	6. Flintshire Lead-furnace.	7. South Staffordshire Puddling Furnace (Model in the School of Mines).	8. English Cupellation-furnace.
	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.
Length of hearth .	39 0	116 0	16 0	50 0	11 6	11 0	5 3	1 9
Width of hearth at middle . .	10 0	19 0	12 0	20 0	7 0	9 6	4 9	4 0
Length of fireplace .	6 6	7 0	4 0	5 0	2 6	2 6	3 9	2 0
Width of fireplace .	1 6	16 0	4 0	10 9	2 6	4 3	3 9	1 10
Depth of fireplace below top of bridge	...	...	3 6	...	2 6	1 9	1 6	1 9
Height of bridge above hearth .	...	...	...	...	1 0	0 9	0 6	...
	tons.		tons.	tons.		ton.		tons.
Weight of charge .	3	...	3·3	85–100	...	1	...	2

In the table on the preceding page the dimensions of typical reverberatory furnaces are given. No. 1 is a German furnace for roasting galena, a long-bedded calciner (*Fortschaufelungsofen*). There are four working doors: 15 cwt. of raw ore are charged in every six hours at the flue end of the furnace. The furnace is thus able to calcine 3 tons of ore in twenty-four hours. No. 2 is the largest reverberatory furnace in the world. It belongs to the famous Washoe plant of the Anaconda Company and is used for the production of copper matte.

No. 3 is the South Wales copper-furnace, the same dimensions applying to the furnaces for ore-smelting, for the smelting of the different kinds of regulus known as "blue metal," for white metal, and for blister copper. No. 4 is an American furnace used for ore-smelting. This is in use at the Butte Reduction Works for matting ores, the charge being 85 to 100 tons. No. 5 is the so-called flowing furnace, formerly used for lead-smelting by the Cornish method. There are two doors on each side. The charge is 2 tons of calcined ore, which is spread over the sloping bed. It melts in about three hours. The charge is then mixed with lime and anthracite, and 2 cwt. of scrap iron are placed in the furnace at the tap-hole. The charge is then remelted, and the furnace tapped by means of an iron bar. The reduced lead flows into a pot outside the furnace, and is followed by regulus formed in the reduction of lead sulphide by iron in the second fusion. Finally, the slag begins to flow, and runs along a gutter into a pit outside. The whole operation occupies eight hours, the consumption of coal being 9 cwt. per ton of ore. No. 6 is the Flintshire furnace used for lead-smelting. There are three doors on each side, the front ones being used for stirring the charge, and the back ones for tapping the slag. The roof is low, and inclines towards the flue end. In the middle there is a hopper for charging. The bed slopes from all sides towards a well in front of the tap-hole, where reduced lead collects. The usual charge is 21 cwt. of ore, the consumption of coal being 12 to 16 cwt. No. 7 (fig. 158) is a South Staffordshire puddling-furnace, which may be taken as typical of this class. There is a model of it at the School of Mines, London. The roof is a low, flat arch, with a slight slope towards the flue end. The working door, placed at one side of the furnace, is about 10 inches above the furnace-bottom. It is closed by a fire-brick slab suspended from a lever. Below the door is the tap-hole, which is closed with sand during the working of the furnace. No. 8 is the English cupellation-furnace, in which lead is separated from silver by the joint action of air and heat. The bed of this furnace is movable and is made of bone-ash, a material that resists the corroding action of the litharge (lead oxide) formed during the process. The movable bed, or *test*, consists of an oval wrought-iron frame lined with bone-ash. One end of the test is perforated with a number of holes through which the litharge, as it forms, flows into a receptacle below. A large portion of the litharge is, however, absorbed by the bed. Air is supplied by means of a tuyère. In the German cupellation-furnace, which is also of the reverberatory type, the roof is movable and the bed fixed. The latter is concave and circular, 8 to 10 feet in diameter; it is made of marl. The roof consists of a movable iron cover lined with clay. A pair of inclined tuyères at one side of the bed supply the necessary air, and the litharge flows off through an opening on the opposite side.

The following illustration, fig. 160, showing the development of copper reverberatory furnaces, is taken from Prof. Gowland's review of advances made in copper-smelting.[1]

It will be seen what enormous strides have been made in increasing the size of copper-matting furnaces. It must be remembered that each increase in size of the hearth portion of the furnace has not been accompanied by a corresponding large increase of grate area, and therefore there has been an ever-decreasing consumption of fuel per ton of ore smelted at each stage of development.

With regard to the reverberatory furnaces used for the refining of copper, there have been fewer and smaller changes in the dimensions. In 1854 the furnaces employed were about 10 ft. × 7 ft., taking a charge of 10 tons. At the present time the largest furnace is probably 30 ft. × 18 ft., refining a charge of about 75 tons. The reason for this is the difficulty of keeping a very large charge at exactly the correct pitch to ensure the maximum toughness. As a matter of fact, for this reason the present practice is to use furnaces of only moderate size, rarely exceeding 18 ft. × 12 ft.

The most important reverberatory furnace in which gaseous fuel is employed is the regenerative open-hearth steel-melting furnace of Sir W. Siemens, fig. 161. Steel is produced in this furnace by three methods: (1) by the fusion of a mixture of pig-iron and scrap iron; (2) by the fusion of pig-iron with rich oxides of iron; (3) by a combination of these two processes, this being the method now almost universally employed.

The regenerative furnace of Siemens is provided with a multiple series of passages in refractory bricks piled one over the other. These passages are traversed alternately by the burnt gases which give up their heat, and by the air or gas which enters to perform the work required in the metallurgical operation. By giving the conduit sufficient length and the hot gases a slight velocity they may be made to issue almost cold, whilst the air which it is proposed to heat gradually reaches hotter and hotter regions.

The usual form of regenerative furnace resembles an ordinary

[1] *Trans. Inst. Min. and Met.*, xvi., 1906–7, p. 283.

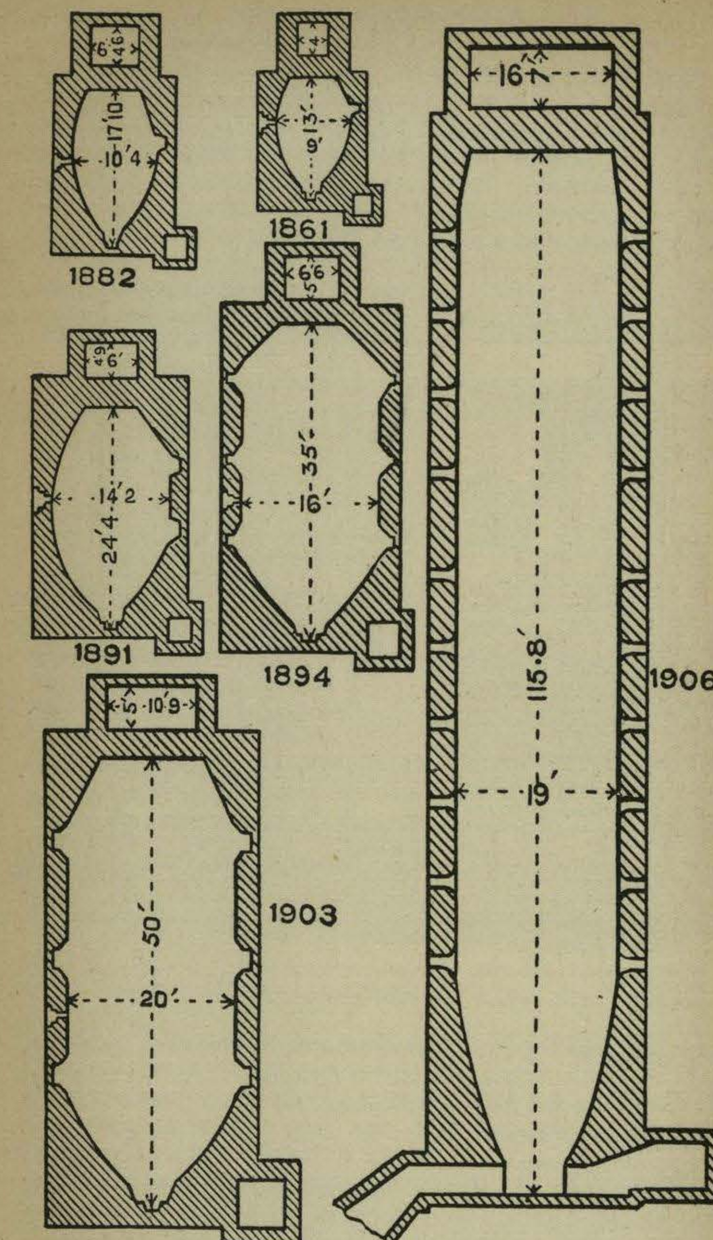


FIG. 160.—Development of the Reverberatory Furnace for Copper-Matte Smelting.

reverberatory furnace symmetrically arranged at its two ends, instead of having the grate at one end and the flue at the other. Two chambers at each end are filled with checker brickwork, space and brick alternately, so that air or gas can freely circulate. The combustible gas enters by a flue into one of these chambers, and the air to effect the combustion enters by another flue into the other chamber. The gas and air are both led to the hearth, where they meet, and the air burning the gas, the flame produced plays freely on the material on the hearth. The burnt gases

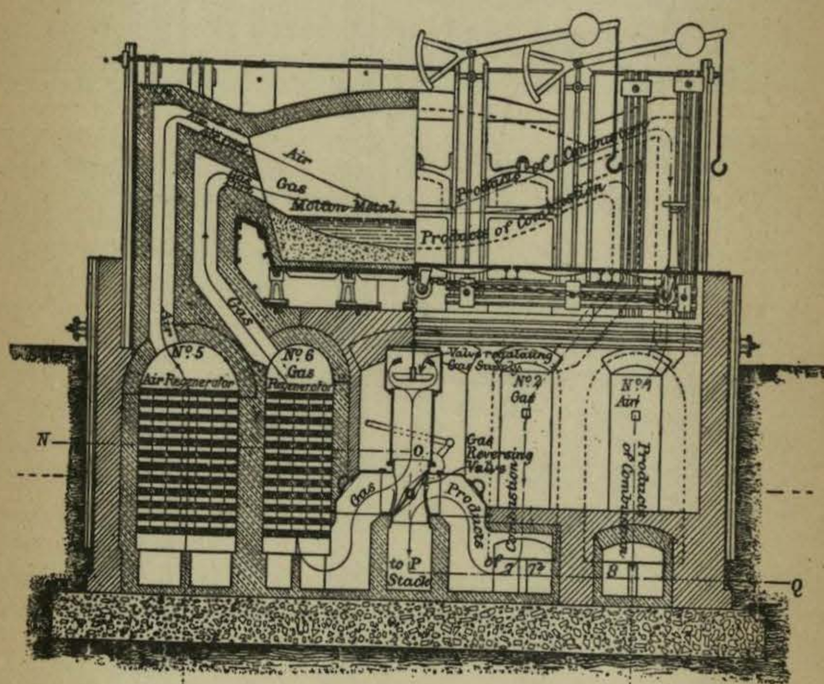


FIG. 161.

then pass into the two other chambers, at the other end of the furnace, and in slowly passing through them give up their heat to the bricks, and finally reach the chimney. In the direct flue from the gas-producer which the gases traverse there are two valves, by means of which the direction of the current may readily be reversed. When the bricks have acquired a temperature but little lower than that of the burnt gas, the valves are turned through an angle of 90°. The combustible gases then enter one of the chambers just heated, and the air enters the other, and in slowly ascending through the chambers they become heated at the expense of the bricks; they meet at the hearth as

before, and in burning develop a degree of heat, the intensity of which depends on the extent to which they have been heated. The products of combustion, after having done their work on the hearth of the furnace, pass through the chambers first mentioned to the chimney. When these chambers become heated, the direction of the current is again reversed, and so on.

By this alternate play of the valvés the air and the combustible gas are heated; the temperature of combustion is thus increased, and a very high temperature may be obtained. At the same time, even if the temperature that would be obtained without this preliminary heating were sufficient for the required operation, it is obvious that by heating the air and combustible gas a great economy in fuel can be effected.

The great advantage of the regenerative furnace is that an oxidising, or, when only a low temperature is required, neutral, or reducing atmosphere may be obtained at will by regulating the supply of air.

The gas, it will be noted, does not come from any fireplace in the furnace itself, but is generated in a separate appliance called a gas-producer. This gas-producer consists essentially of a fire-grate on which a thick layer of fuel is maintained. The combustible part of the fuel, usually small coal, is converted very largely into carbonic oxide, hydrogen, and hydrocarbons, which are carried forward through flues to the furnaces in which they are burnt.

In the original Siemens furnace a dip-roof was used to deflect the flame on to the hearth, but in the modern furnace the roof is arched to give a larger combustion chamber, so that the gas burns out of contact with the roof or the charge. The heating of the charge is thus done almost entirely by radiation, which, apart from other advantages, has greatly increased the life of the roofs.

The tendency of late has been greatly to increase the capacity of open-hearth furnaces for steel-making. Charges of 40 to 50 and even 75 tons have become common, while furnaces holding charges of 100 to 200 tons are being used in the Talbot continuous process.

In some cases tilting furnaces are used, so that the charge can be poured instead of being tapped as in the stationary furnaces; and in the very large furnaces containing 100 tons and upwards a tilting furnace is necessary. These are of two types, known as the Campbell and the Wellman. The former is supported on rollers set in the arc of a circle, having its centre in the axis of the furnace, and the latter is supported on rockers, and tilts forward when pouring the charge. In the Campbell furnace, whatever its position, the ports are always fully open to the regenerators; but in the case of the Wellman, the ports are more or less shut off as the furnace is tilted for pouring the charge.

In order to economise labour, various forms of furnaces have been suggested: amongst these may be mentioned the Stetefeldt, in which the material is allowed to fall as a shower of dust through

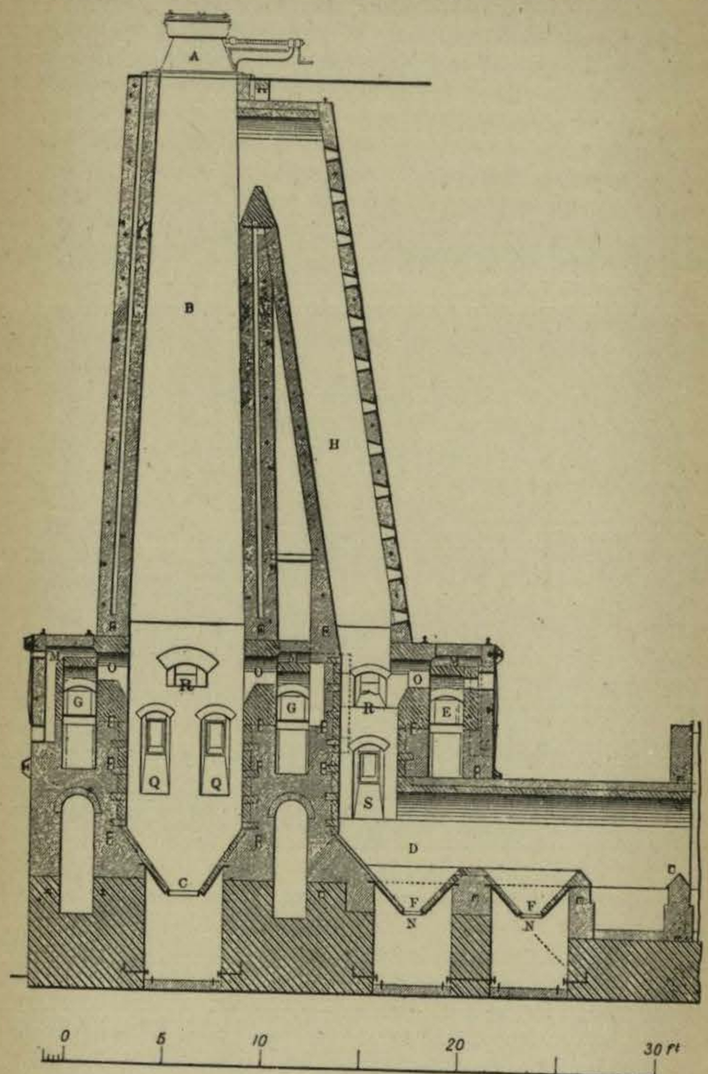


Fig. 162.

a shaft that is traversed from bottom to top by the flame from a lateral fireplace. This furnace is used for chloridising roasting of silver ores, and the pulverised ore, mixed with salt, is charged at the top of the shaft B (fig. 162) by the aid of a mechanical

feeder arranged at A on the top of the shaft. The ore falls in a slow stream down the shaft and encounters the hot gases from the gas-generators G G. For the ore which is carried along the flue H, through which the gases escape, a third gas-fire E is provided. This assists the action of the main shaft, and causes the ore to reach the flue D in a completely roasted and chloridised state, if it has not already been discharged through the hopper C. The fireplaces and arches are of fire-brick; the remainder of the furnace is of common brick. The vertical shaft is usually 30 to 45 feet in height, and 4 to 6 feet square at the base. These furnaces roast about 40 tons of ore in twenty-four hours. In Utah as much as 64 tons are treated daily. In the Stetefeldt furnace the chloridising roasting action is very rapid and complete, whilst the expenditure of labour and of fuel is small.[1]

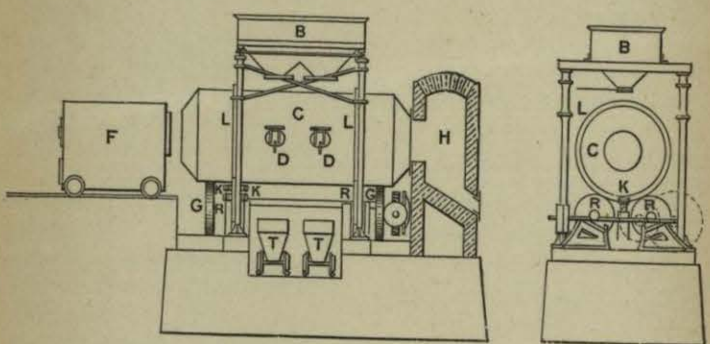


Fig. 163.—Brückner Cylinder.

The Brückner cylinder (fig. 163) is a successful modification of the reverberatory furnace, designed with a special view to the economy of labour. The roasting chamber or laboratory part of the furnace consists of a horizontal iron cylinder C, about 8 feet in diameter, which may be lined with fire-brick. The ore is introduced into this cylinder in the state of coarse powder from an ore-bin B, through two doors D D in the side of the cylinder, the latter being first rotated so as to bring the doors vertically beneath the two hoppers of the bin. The openings are closed by slides, by means of which the supply of ore to the cylinder can be controlled.

When the charge for the operation is received in the cylinder, the two doors D D are closed and bolted down, and the cylinder, which rests upon large friction rollers R R, is slowly revolved by means of the gearing G G, so that fresh surfaces of the ore are continually exposed to the action of the heated gases from a hearth F. This hearth is mounted upon wheels and stands

[1] *Engineering*, vol. xl., 1885, Sept. 25, p. 293.