from certain slags. Silicates of iron and zinc are formed, while sulphur retains the copper in the regulus.

Chemical Agents.—Certain sulphurising agents are employed in metallurgical processes. These are specially useful in the treatment of silver and copper. The agents are iron or copper pyrites, barium or calcium sulphates, and, less frequently, alkaline sulphides. Nickel and cobalt behave with regard to arsenic as silver and copper do in the case of sulphur. These metals may be protected, by means of their affinity for arsenic, from the scorifying action of silicates.

Chlorine is largely used in the treatment of gold and silver ores. It is employed in the gaseous state as an aqueous solution, or in the form of alkaline hypochlorites. The perchlorides of iron, copper, and mercury act as chloridising agents by being converted into lower chlorides. They are obtained usually by the direct action of hydrochloric acid on peroxides. Iodine in the form of iodide is used in the metallurgy of silver, and bromine in that of gold.

The agents employed for effecting the solution of metallic substances are very varied. The most important solvent is water, which is used for dissolving sulphates of iron, copper, zinc, and silver, and chloride of gold. Other salts are dissolved by salt solutions; thus, chloride of silver is dissolved by an aqueous solution of sodium chloride, or hyposulphites of sodium or calcium. The use of very dilute solutions of potassium cyanide in the extraction of gold[1] has assumed great importance, and numerous patents for its production have been secured;[2] sodium cyanide, also, is now largely used in the treatment of gold and silver ores. Metallic oxides are dissolved by acids; gold and platinum are dissolved by aqua regia; and in the amalgamation of gold and silver, mercury is the solvent employed.

In metallurgical processes there are scarcely any limits to the use of ordinary chemical reagents beyond those imposed by the price of the material.

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[1] Rose, *Metallurgy of Gold.*

[2] *Mineral Industry*, 1894, p. 79.

CHAPTER IX.

FURNACES.

Materials used in the Construction of Furnaces.—In addition to the ordinary building materials used for the exterior portions of furnaces, refractory bricks and materials are required for the interior where a high temperature and the scouring action of metallic oxides have to be resisted.

There are three classes of refractory materials:—

1. *Acid*—Dinas rock, ganister, and most fire-clays.
2. *Basic*—Dolomite and magnesite.
3. *Neutral*—Bauxite, chrome-iron ore, graphite, and a few fire-clays.

Acid Refractories.—Siliceous materials are most generally employed, as in the great majority of cases all that is required is a material capable of resisting high temperatures, and also mechanically strong under great variations of temperature. It is only when the chemical reactions involved are such that a siliceous lining would interfere or be fluxed away that neutral or basic linings are used. For roofs, side walls, and all those parts of the furnace which do not form part of the hearth or "laboratory," siliceous bricks are almost universally employed in all metallurgical works. Thus all copper-smelting furnaces, all reheating and annealing furnaces, whether for copper, steel, or other metals, ore-roasting furnaces, many steel-smelting furnaces, and practically all blast furnaces, are built with some kind of siliceous fire-bricks, sometimes nearly pure silica, when very high temperatures have to be resisted, at other times of different kinds of fire-clay.

The question of contraction and expansion is an important consideration in selecting a fire-resisting material, as some expand much more than others, and for certain parts of a furnace this may be a serious disadvantage, while for others it is of no consequence, and may even be an advantage.

These materials may be used either in the natural state or as bricks. Of the natural materials, sandstones are most largely employed, the best varieties being those in which the quartz grains are cemented by a siliceous material. In the form of quartz, silica is able to resist all temperatures up to that of the oxyhydrogen blowpipe. Coarse-grained sandstones, such as millstone grit, are frequently advantageously used. The Dinas rock found in the Vale of Neath, South Wales, is an example of this type. It usually contains 98 per cent. of silica. The pulverised rock is mixed with a little lime or clay to make it cohere, and is pressed into bricks. These resist a very high temperature, and are especially useful for the arches of reverberatory furnaces, as they expand with heat. Their composition, however, does not enable them to resist the action of metallic oxides. In steel-melting furnaces, where Dinas bricks are used for roofs, the tie-rods must be slackened as the heat increases, and tightened when the furnace subsequently cools. Ganister is a siliceous material, somewhat similar to the Dinas stone, found in the lower coal-measures of Yorkshire; most fire-clays are also siliceous, that is, they contain an excess of silica.

Fire-bricks are mostly made of fire-clay, mixed with quartz or burnt clay. The admixture of graphite is not usual for fire-bricks, but is used for refractory crucibles in which metals and alloys are melted.

Fire-clays consist essentially of hydrated aluminium silicates, having the following composition:—

SiO_2.	Al_2O_3.	H_2O.
55 to 65	22 to 35	10 to 15

When lime, magnesia, potash, or soda are present in quantities exceeding 1 per cent. the clay becomes fusible. In aluminous clays less than 0·7 per cent. of these oxides does not depreciate their refractory value, but, as a rule, a small amount of these oxides or of ferrous oxide is sufficient to condemn a clay. Thus ordinary shale fuses at a comparatively low temperature, on account of its large percentage of alkaline oxides and ferrous oxide.

The plasticity of clays depends upon the fineness of the particles and the amount of water present. Plasticity is tested for by means of standard needles, the degree of penetration being noted under definite pressure. After being calcined, clays cease to be plastic when moistened, on account of the molecular alteration brought about by the calcination. Fire-clays contract when heated, even after all their combined water has been driven off, but heating up to 100° does not affect plasticity; it merely drives off the hygroscopic water. The quality of the clay is largely dependent upon the free silica it contains. Windsor fire-bricks, useful when the temperatures are not high, are made of a mixture of sand and fire-clay in equal proportions.

The mortar employed for setting fire-bricks is prepared from the same materials as the bricks themselves, or from good clay. Lime mortar must not be employed for fire-bricks or fire-clay.[1]

Sexton[2] gives details as to refractory materials, while excellent articles by Ferry[3] deal with the principles underlying the successful manufacture of fire-brick.

Basic Refractories.—These are now very largely employed in the manufacture of steel, both for lining Bessemer converters and open-hearth furnaces. There are only two materials used to any extent, viz. burnt dolomite, known as "basic material," and magnesite. The use of a basic lining is essential both in the Bessemer and open-hearth process when a phosphoric pig-iron has to be used, as without it the phosphorus present cannot be removed. Dolomite containing as little silica as possible, preferably not exceeding 1·5 per cent., is calcined at a very high temperature to completely expel the CO_2 and thoroughly shrink it, after which it does not very readily absorb moisture, and if protected from the direct action of the air, can be transported considerable distances by rail without serious deterioration. After calcination it is ground fairly fine, and either mixed with tar and moulded into bricks or used as a ramming for making the furnace lining: in the case of open-hearth furnaces it is more usual now not to mix it with tar, but to frit it on to the furnace-bottom in the dry state.

Magnesite forms a still better refractory lining than basic material, and magnesite bricks are now very largely used. The magnesite is "dead burnt" and then moulded into bricks, sufficient fusible material being added to frit the magnesia together and form a hard brick which will bear transport. These bricks are much more expensive than "basic material," weight for weight, but they last so much longer that for certain parts of steel furnaces the extra cost is more than compensated for by the longer life.

Lime, from a chemical standpoint, is just as good as basic material; but although it is extremely refractory, no one has yet succeeded in producing a satisfactory mechanical brick, as, owing to the readiness with which it becomes hydrated, the bricks rapidly disintegrate.

Neutral Refractories. — These are not very largely used, although in some special cases the hearth or "crucible" part of the furnace is lined with them. Thus bauxite has been used for resisting the action of metallic oxides, but it is not very refractory as compared with basic materials. It consists essentially of hydrated alumina, containing varying quantities of oxide of iron, but only the purest varieties are suitable for the manufacture of

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[1] Snelus, *Journ. Iron and Steel Inst.*, 1875, p. 513.

[2] Sexton's *Fuel*.

[3] *Mineral Industries*, vol. iv., 1895, p. 113; *ibid.*, vol. vii., 1899, p. 129.

bricks, and it should approximate to the following percentage composition:—

Al_2O_3.	F_2O_3.	SiO_2.	H_2O.
85 to 90	1·0 to 3·0	2·0 to 4	10 to 15

Another neutral material which has been used to a limited extent is chrome-iron ore, which has been found to be useful to form a neutral joint between basic and acid materials; various attempts have also been made to use it as a lining for open-hearth steel furnaces, but this has not been successful. Oxides of iron have also been used for the hearths of different furnaces, and also the slags produced in various operations, many of which may be regarded as neutral bodies.

Graphite in admixture with aluminous fire-clays has also been used for some special purposes, but, apart from the manufacture of crucibles, has never been largely employed.

Crucibles.—For special metallurgical purposes, crucibles, as in the case of cast steel, and retorts, as in case of zinc and arsenic smelting, are used.

Crucibles are required to resist (1) high temperatures; (2) alternating temperatures; and (3) the corroding action of metallic oxides. They must also not be brittle or "tender" when hot. They may be made of clay, magnesia, graphite, gas-carbon, and many other materials, according to requirements. When made of clay, two-thirds are raw clay and one-third is burnt clay, or pulverised material obtained from old but clean pots. By this addition, contraction on drying is avoided.

In order to test fire-clay, a piece is fashioned with sharp angles, dried, and exposed to a white heat in a muffle; it is then examined to see if the edges have fused. A similar test should be made in a reducing atmosphere, the test-piece being placed in a crucible packed with charcoal.

In order to test the resistance of a crucible to corrosion, it may be half filled with copper, which is then melted, and a little borax inserted so as just to form a ring round the edge of the molten metal and yet leave the centre free for oxidation. The borax will absorb the oxide and rapidly corrode the crucible unless it be of excellent quality. The behaviour of the crucible under the weight of the copper melted indicates the other qualities of the crucible. In selecting clay for crucibles, special care must be taken that neither iron pyrites nor more than a minute percentage of potash or soda is present. A small quantity of lime is of less importance.

The so-called plumbago crucibles are made of clay and graphite, in the proportion of 51 of the former to 49 of the latter. Only certain varieties of graphite can be used for crucible-making, the texture being of great importance: the suitability can only be determined by experiment. The graphite is picked, ground, sifted, and mixed with the fire-clay, and left for some time to "mellow" after it has been kneaded damp. The crucibles are moulded, dried, and then burnt in kilns. Obviously, an oxidising atmosphere must always be avoided. In order to prevent absorption of moisture and salts, as in cases of shipment, and to enable rapid alterations of temperature to be better withstood, the finished crucibles are dipped in milk of clay, dried, glazed, and then dipped in tar. Crucibles made in this way by the Battersea Crucible Company will stand forty meltings of gold without sensible deterioration.

The pots used in the chlorination process for parting gold and silver are soaked in borax solution, dried, and heated. The borax then melts and clogs the pores, and prevents the escape of the silver chloride, which is very fluid.

Classification of Furnaces.—The words *hearth*, *forge*, and *furnace* are applied to structures in which ores or metals are submitted to high temperatures. A furnace is composed of an interior part, of fire-resisting materials, and an exterior part, built for the purpose of consolidating the interior structure. Furnaces may be divided into two classes—(1) those in which the charge and solid fuel are in intimate contact, there being no independent hearth or fireplace; and (2) those in which the solid fuel and ore are kept separate, the fuel being burnt in an independent hearth. The first class of furnaces may be subdivided, according to their height and construction, into *hearths* and *shaft-furnaces*; the former are appliances that usually do not work continuously, whilst in the shaft-furnace the action is continuous. The second class is subdivided into (*a*) *reverberatory furnaces*, a group in which gas-furnaces may be included; and (*b*) *retort-furnaces*. In the former, the charge only comes in contact with the flame of the fuel, whilst in the retort-furnaces it does not come into contact with the combustible gases of the fuel at all, but is separated from them by walls that merely transmit the heat. These walls usually form part of separate closed vessels, crucibles, muffles, or retorts, but occasionally they are part of the furnace itself, as in the case of the Bessemer converter, which may be described as a vessel usually pear-shaped, in which the impurities contained in the metal treated constitute the fuel, which is burnt by a forced current of air. Furnaces may be further divided into those worked by means of a natural current of air, and those worked by a forced current of air. The classification of furnaces may then be summarised thus:—

I. HEARTHS.

(*a*) Worked by means of a natural current of air. (1) Roasting-hearth (piles, stalls, pits, kilns); (2) Liquation-hearth.

(*b*) Worked by means of a forced draught (the smith's forge, iron refinery).

II. SHAFT-FURNACES.

(*a*) Draught-furnaces (iron ore calciners).

(*b*) Blast-furnaces (iron blast-furnaces, Raschette-furnace, Pilz-furnace, cupola-furnace).

III. REVERBERATORY FURNACES.

(*a*) Worked by means of a natural draught (puddling-furnace).

(*b*) Worked by means of a forced draught (cupellation-furnace).

(*c*) Automatic reverberatory furnaces (rake-calciners).

IV. CLOSED-VESSEL FURNACES,

in which may be included various forms of crucible-, tube-, and retort-furnaces, converters, etc., and which may be divided, according to the process carried out in them, into—

(*a*) Smelting-furnace (ordinary assay-furnace).

(*b*) Oxidising-furnace (copper and steel converter).

(*c*) Liquation-furnace (bismuth).

(*d*) Distillation-furnace (zinc, mercury).

(*e*) Sublimation-furnace (arsenious acid).

(*f*) Cementation-furnace (cement steel).

V. ELECTRICAL FURNACES,

in which the combustion of carbon need not, even indirectly, produce heat.

General Principles.—Whether natural or forced draught is used, the general principles involved in fuel combustion apply. The fuel employed in either case may be the same, but the products of its combustion may be widely different. The form and dimensions of the furnace will obviously give rise to very varied results; on them depends the amount of fuel that can be burnt in a given time, and the degree of perfection of the combustion that can be attained, the temperature actually engendered being dependent on the calorific power of the fuel. In a furnace without an independent hearth, the most important part is that in which the work is principally done. This may be conveniently localised as the zone of combustion. Thus, as Gruner expresses it, for a given fuel burnt in a certain way, the heat developed will simply be proportional to the weight of fuel burnt, whilst the temperature depends on the rapidity of combustion—that is, on the ratio between the volume of the zone of combustion and the weight of coal or coke burnt in an hour. The smaller this ratio, the higher the temperature will be.

In order to show how varied the conditions may be, the following two cases may be cited:—(1) An ordinary coal-fired Gjers calcining kiln, such as for years has been almost universally used in the Cleveland district for calcining ironstone with a natural draught of air. The height of the furnace is 33 feet, and its total internal capacity is 8000 cubic feet; but the work of the furnace—namely, that of driving off carbonic anhydride and moisture from an iron ore—is not confined to a limited zone; indeed, the volume of this zone of combustion may be taken to be about 1400 cubic feet. Compare this with (2) a modern blast-furnace, such as that used at the present time in Middlesbrough. The height of the furnace is about 76 feet, and its output may be 4000 to 5000 tons per month, or about 140 to 160 tons of pig-iron in twenty-four hours. In this case the air previously heated is driven in, a course which is necessary in order to overcome the resistance of the superincumbent and partially fused mass of ore, fuel, and flux, and the result is that the combustion of the fuel is more or less limited to an intensely hot zone of combustion.

Furnaces with independent hearths are usually reverberatory furnaces, although there are cases in which vat-shaped furnaces are supplemented by fire-grates, which are usually symmetrically arranged round the base. The object of isolating the fuel from the ore is to prevent chemical action of a kind that is not wanted, and generally to enable the nature of the products of combustion admitted into the furnace to be controlled. It would be useless, for instance, to admit torrents of carbonic oxide into a furnace where an oxidising action was wanted, and, conversely, the predominance of an atmosphere of carbonic anhydride would be fatal to a reducing action.

It is usual to consider a reverberatory furnace as consisting of a grate to hold the fuel, and the "laboratory" portion in which a given operation is conducted. The nature of the operation may be infinitely varied, and the temperature of the laboratory may vary from the dull red heat required for roasting pyritic ores to the intense heat required for melting steel. Obviously, the dimensions of the grate in relation to those of the laboratory will vary considerably according to the nature of the operation to be carried on in the furnace.

I. Hearths.—A hearth is a low furnace in which the material to be treated is exposed to the direct action of solid fuel. Heaps, stalls, and kilns for roasting ore are also included in this category, as the action of the fuel is the same. Consequently, hearths are not necessarily enclosed furnaces, but may exist without the aid of any brickwork at all. The pyramidal heaps, in which the roasting of copper ores is effected, are free or unwalled, about 30 feet square at the base, and built upon level ground. A bed of wood, about 1 foot in thickness, is formed, and on this alternated layers of ore and charcoal are piled to a vertical height of 10 feet. Some ironstone from the coal-measures may be roasted in heaps without the addition of fuel. The proportion of bitumen in the copper shale of Mansfeld is almost sufficient for its calcination. With sulphuretted ores, a bed of fuel is used, the burning sulphur keeping up the roasting temperature. Peters[1] describes the large-scale American methods of heap-roasting. The liquation-hearths formerly employed for separating easily fusible constituents out of metallic mixtures also belong to this class.

Hearths worked by means of a forced current of air may be employed for melting, or for heating a substance to a very high temperature without altering its state of aggregation, as in welding and forging metals that are not readily fusible.

An example of this class of hearth is the refinery formerly largely used in the manufacture of wrought iron. It consists of a rectangular hearth, provided with inclined tuyères, through which air is blown upon the surface of the molten iron, so that the silicon in the iron is oxidised, forming with a portion of the iron a fusible ferrous silicate. This process is confined to a few localities making special qualities of wrought iron.

Further examples are afforded by the shallow hearths used for lead-smelting. In the north of England a furnace of this kind, known as the *ore-hearth*, is sometimes used. It consists of a cubical chamber about 22 inches side, lined with cast iron. In the back wall is fixed a tuyère for the introduction of the blast. In front is the work-stone, which is placed at a slight inclination to the bottom of the hearth. The melted lead flows from the hearth down an oblique channel in the work-stone to a lead pot placed before the work-stone. The operation lasts about twelve hours, the production being 1 to 1½ ton of lead. Peat was formerly used as fuel, but it has now been abandoned, and coal is generally employed.

In hearths and kilns of this class the introduction of cold material renders the combustion of the fuel, whether gaseous or solid, more or less imperfect, so that the products of combustion contain an inordinate amount of unburnt gases, especially of carbonic oxide. As a rule, in a kiln the position of the zone of combustion is fixed, but it occurred to Hoffmann,[2] a German architect, to devise a kiln in which the position of the zone of combustion can be varied at will, and he thus succeeded in effecting a considerable economy of fuel. In an ordinary kiln there is a continuous ascending column of gas, and a descending column of solid material. In the Hoffmann and kilns of this type, on the other hand, the solid material remains stationary, while the gaseous current alone moves. The kiln may be either circular or oval in section. This is shown in fig. 148. It consists of a circular tunnel, *M M*, which can be divided into any number of compartments, twelve or sixteen being the usual number. These compartments are, however, in direct communication with each other except at one point, where an iron plate, *p p*, placed across the tunnel, interrupts the continuity. This plate may be inserted through the roof of the tunnel down grooves, *n n*, provided for its reception, in the walls. Each space between two sets of grooves is provided with an internal flue, $E_1 E_2$, which, by the removal of a damper, can be placed in communication with a central chimney, and each space has also a door, *B B*, in the outer wall. Only two of these doors are open at a time. The whole of the tunnel is kept full of material (ores to be calcined, or bricks to be burnt), except one compartment, which is always empty. The position of the empty compartment varies from day to day. Let the plate occupy the position, *p p*, shown

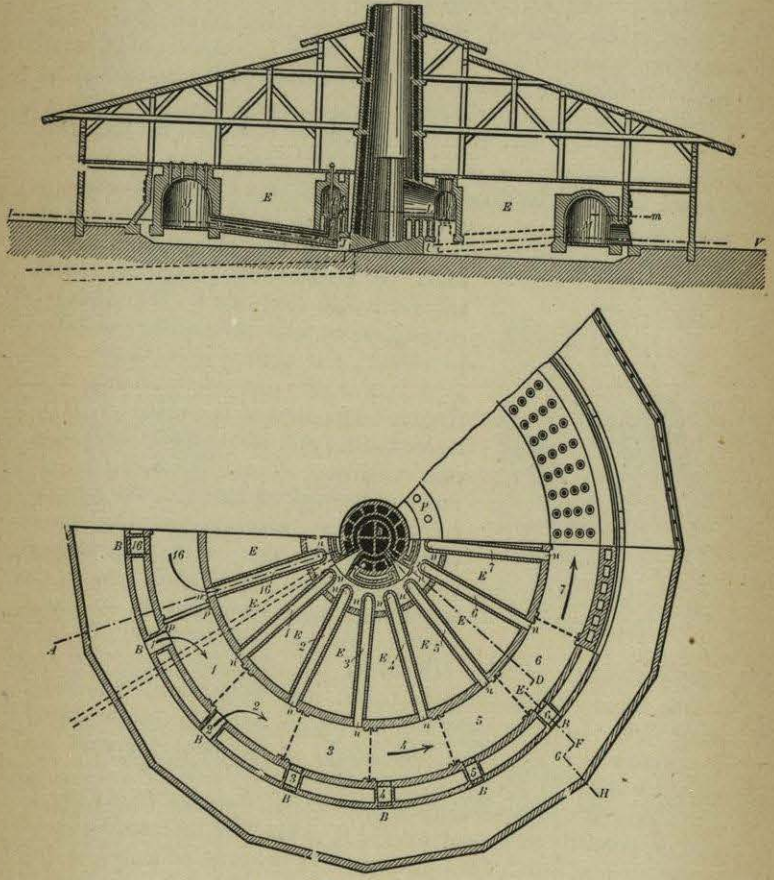

Fig. 148.

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[1] Peters, *Copper Smelting*, chaps. vi. and vii.

[2] *Annales des Mines*, 6th Series, vol. xx. (1871), p. 325.

in fig. 148. The newest material has been charged in behind it into compartment 16. Air enters in front of it through the open door of the empty compartment No. 1, and through the door, also open, of the next compartment, which contains finished material that has been longer in the furnace than the rest, and has but little heat to give up to the incoming current of air. This current is drawn by natural draught round the entire tunnel, and can only enter the chimney through one or more of the flues that have been opened behind the plate. After an interval of twenty-four hours from the last charging, the position of the iron partition is shifted to the next groove to the right, the compartment No. 1 is filled, and the one, No. 2, in front of the plate is emptied. Thus new material is continually kept behind the plate, and finished material in front of it. Air entering comes in contact with material which gradually increases in temperature, for it will be obvious that the position of the hottest part of the furnace must be continually travelling round the circle, and that in a number of days, corresponding with the number of compartments, the zone of combustion will have travelled completely round the circuit. The air and the material to be treated enter and leave the furnace in a cold condition, so that there can be no waste of heat, provided that the adjustment of the dampers in the flues through which the gases pass to the chimney is carefully effected. In order to remedy local irregularities of combustion, air may, if necessary, be admitted through suitable orifices in the roof.

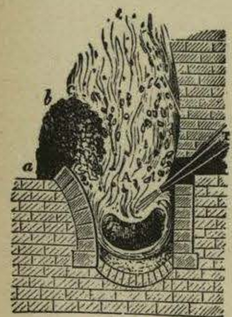

FIG. 149.

The volume of each compartment may vary from 282 to 1765 cubic feet. In order to facilitate charging and to secure perfect uniformity of temperature, the height of the tunnel should not exceed 9 feet.

In Catalonia a low hearth, the Catalan furnace (fig. 149), is still occasionally to be met with. It is used for the production of malleable iron direct from the ore. It is made of blocks of cast iron and has a sandstone bottom. The tuyère is made of sheet copper. The blast is supplied by a water-blowing machine, or *trompe*, which may be made from a hollow tree trunk, 15 feet high, at the top of which is a water-box with a plug. The water falls down the pipe into the wind-box, carrying air with it, and causing a pressure of 1½ to 2 lbs. per square inch in the hearth.

II. **Shaft-furnaces.**—In most of the members of this group the fuel and ore are charged into a common receptacle, the major axis of which is vertical. Certain of them, as the kilns in which limestone or ore is calcined, are worked by a natural current of air, the furnace itself forming a capacious chimney.

The form of these furnaces is very varied according to the nature of the ore and of the fuel employed. Furnaces of this kind may be egg-shaped, cylindrical, or conical. Small kilns with circular horizontal section effect the most uniform roasting, give rise to the least loss of heat by radiation, and wear well. The height is dependent on the size of the pieces and on the fusibility of the ore. The width is dependent on the quantity of ore to be roasted. In large kilns of circular section it is difficult to maintain a uniform temperature. Large kilns have consequently an elliptical or rectangular section. In the latter case the corners are rounded off.

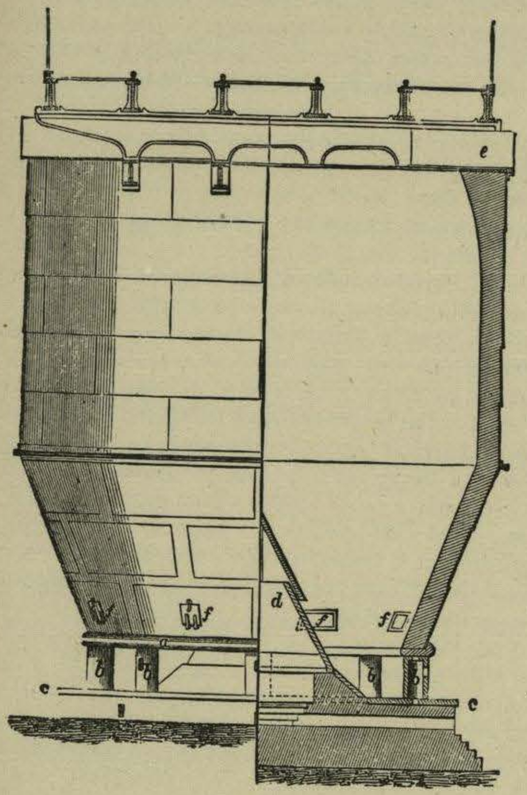

FIG. 150.

The best examples of this type of furnace are afforded by the kilns employed for calcining iron ores. One of the best forms is that of Gjers (fig. 150), which is extensively used in the Cleveland district. The drawing, to the scale of 10 feet to the inch, shows this kiln partly in elevation and partly in section. The body is of fire-brick cased with wrought-iron plates. The bottom of the brickwork rests on a cast-iron ring, *a*, and the whole is supported by cast-iron pillars, *b*, leaving a clear space between the bottom of the kiln and the floor. The latter is covered by iron plates, *c*, on the centre of which is fixed a cast-iron cone, *d*, 8 feet in height and 8 feet in diameter at the base. This causes the descending roasted ore to pass outwards. Fresh ore and coal are constantly being added from the filling gallery, *e*. Around the lower tier of plates are openings, *f*, which are usually closed by doors, but which serve for the admission of air or tools in case of the ore becoming clotted. These kilns are usually 33 feet in height, 24 feet in diameter at the widest part, and have a capacity of 8000 cubic feet. They calcine 1000 tons of iron ore per week, the consumption of coal amounting to 1 ton for 25 tons of ore.

The most important member of the group of furnaces without separate hearth is the blast-furnace. As its name implies, it is worked by a forced current of air supplied by blowing-engines. In former times charcoal was exclusively the fuel employed, whilst at the present time coke is mostly used. Raw fuel (coal or anthracite) is only adopted in special cases. The modern blast-furnace, in which coke is used as fuel, is 70 to 80 feet in height, some of the larger examples attaining to 100 feet. Charcoal blast-furnaces are considerably smaller. Formerly the blast-furnace was a heavy conical mass of masonry some 30 feet in height. It is now a much lighter structure, formed of a wrought-iron casing lined with brickwork. In order to distinguish it from the older forms, it is termed a cupola blast-furnace. In the upper opening, or throat, fuel, ore and flux are charged, being allowed to fall into the furnace, usually through some form of appliance for distributing the charge. In the lower narrow portion of the furnace, highly compressed air is forced through a number of horizontal nozzles or tuyères arranged in a circle. When the blast is previously heated, water-cooled tuyères are always employed, which consist of hollow truncated cones provided with an annular space all round, in which water freely circulates. In the space in front of the tuyères the combustion of the fuel is largely effected, this being already highly heated in its descent through the furnace, and a temperature of more than 2000° is obtained. The plane in the blast-furnace where the greatest diameter is reached is termed the *boshes*, and the cylindrical portion at the base is the *hearth*, in which the molten material collects. The top of the furnace is surrounded by a charging-gallery, and is usually covered in by an iron cup and cone, the latter of which may be lowered by a counterpoise and winch, or by a hydraulic cylinder, when material is to be charged in; the waste gases pass through a side tube, whence they are led to the stoves for heating the blast, burnt under boilers, or used in internal gas-combustion engines. The stack is carried on an iron ring resting upon iron columns, the object being to have all the working parts of the furnace readily accessible, so that they can be repaired from time to time.

The hearth or crucible of the furnace is circular, and its capacity largely determines the output of the furnace. The bottom is made of refractory sandstone, carefully jointed. The tap-hole should be placed midway between two tuyères, so as to be cool and easy of access and on a level with the bottom of the furnace. The slag notch should be placed away from the tap-hole and at a certain distance below the tuyères. The iron is run into sand moulds, forming *pigs* about 3 feet long.

A large modern blast-furnace produces 75 to 200 tons of pig-iron in twenty-four hours, and in American practice a daily output of 400 to 500 tons is not unusual, whilst small charcoal blast-furnaces yield only 5 tons in the same time, and large ones up to 40 tons.

A convenient classification of blast-furnaces is that based on the ratio of the maximum diameter to the height. In this manner the following three classes may be distinguished:—

1. Squat furnaces, in which the height is less than, or equal to, three times the diameter, $\frac{H}{D} < 3$.

2. Ordinary furnaces, in which the ratio $\frac{H}{D}$ varies between 3 and 4, but is usually about 3·5.

3. Elongated furnaces, in which the ratio $\frac{H}{D}$ is greater than 4.

The following table gives comparative data of the dimensions and workings of ten blast-furnaces used for the smelting of iron, the outlines being shown in fig. 151.

	Cubic Capacity.	Total Height.	Diameter at Hearth.	Diameter at Boshes.	Diameter at Throat.	Daily Output.	Time in Furnace.	Fuel per Ton of Metal.
	cub. ft.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	tons.	hours.	lbs.
1	30,000	85 0	8 0	28 0	19 0	70	150	2308
2	18,000	80 0	11 0	22 0	16 0	270	21	1863
3	15,000	75 0	11 0	20 0	15 4	175	24	2116
4	14,000	75 0	8 0	21 0	14 0	107	36	2130
5	8,824	73 8	9 6	15 6	11 9	142	20	1943
6	6,676	72 4	8 6	14 0	9 6	114	19	1697
7	2,000	50 0	5 6	10 0	5 6	48	8	1870
8	1,872	49 8	4 6	10 4	3 4½	24	10	1365
9	1,235	37 3½	5 8	8 4½	3 1½	24	4	1653
10	1,000	37 6	5 6	7 9	3 0	20	7	1585

In the first six furnaces coke is the fuel employed, whilst charcoal is used in the last four. The names and situations of the furnaces are: 1. Newport, England; 2. Edgar Thomson "F," Pittsburg, United States; 3. North Chicago, No. 6, Chicago, United States; 4. North Lonsdale, No. 3, Lancashire; 5, Union, No. 3 and No. 4; 6. Union, No. 2, Chicago; 7. Midland, Crawford County, Missouri, United States; 8. Treibach, Austria; 9. Ferdinand, Hieflau, Austria; 10. Wrbna, Eisenerz, Austria. The first four of these furnaces belong to the second class, in which $\frac{H}{D}$ is less than 4, whilst the last six are elongated furnaces in which the ratio $\frac{H}{D}$ is greater than 4. The following are examples of the first class, in which $\frac{H}{D}$ is 3 or less than 3:—

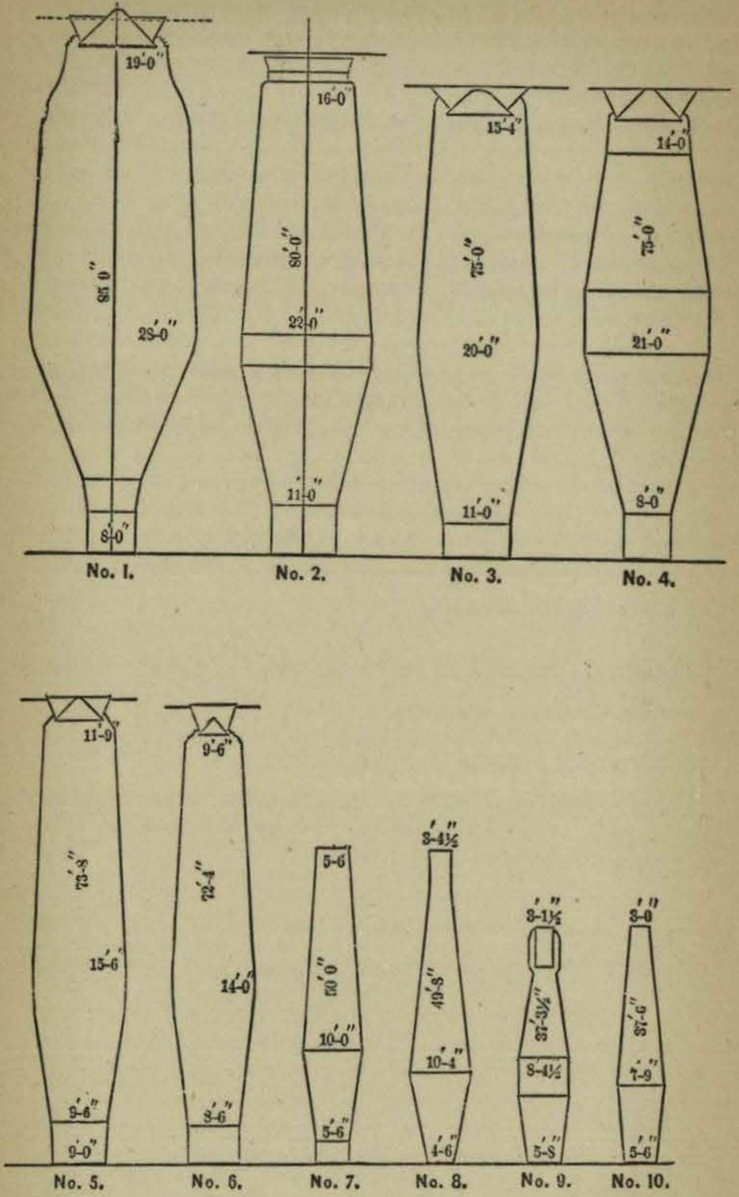

FIG 151.—Outlines of Iron Blast-Furnaces.

	Name.	Cubic Capacity.	Height.	Diameter at Throat.		Diameter at Boshes.		Daily Output
		cub. ft.	ft.	ft.	ins.	ft.	ins.	tons.
11	Longwy, France .	14,656	65	13	6	23	0	40
12	Clarence (old type) .	6,003	50	7	10	16	6	30
13	Thornaby ,, .	12,784	60	14	9	20	0	...
14	Ormesby ,, .	40,984	90	15	9	30	0	...

In furnaces of this type the working is irregular on account of the contraction at the throat, which renders it difficult to apply any mechanical method of distributing the charge uniformly.

The student should refer to the excellent paper by Grenville Jones on "A Description of Messrs Bell Brothers' Blast-Furnaces from 1844 to 1908"[1] for a well-illustrated historical account of the development of blast-furnace practice in this country.

A modern American blast-furnace is shown in fig. 152, in which an automatic charging apparatus is seen, which consists of an inclined girder tramway, on which there are generally two lines of rails, so that the weight of the ascending skip is balanced by that of the descending skip on the other line.

These skips are made of strong sheet steel, and carry about 2 tons. Arrangements are made by means of guide rails at the top of the tramway for the automatic tipping of the contents of the skip into the double cup and cone. The skips are filled from hopper-shaped bins which are arranged near the foot of the furnace hoist. Separate bins are provided for ores, coke, and limestone.

It was formerly the practice to allow the waste gases to burn

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[1] *Journ. Iron and Steel Inst.*, 1908, iii. p. 59.