

PART II.—METALLURGICAL TREATMENT.

Originally most of the Broken Hill companies smelted their ore at Broken Hill, but one by one, especially since the treatment of sulphide ore became necessary, the various companies dismantled their old and erected fresh plants on the seaboard—*e.g.*, the British Company, at Port Pirie; the Junction Company, at Dry Creek; Block 14, at Port Adelaide; and the B.H.P. Company, at Port Pirie, all in South Australia; and the Sulphide Corporation (Central Mine), at Cockle Creek, near Newcastle, New South Wales. Since then, one by one, these reduction works, with the exception of the B.H.P. Company's Port Pirie works and the Cockle Creek works, have ceased operation. A Customs works, erected at Dapto, New South Wales, largely to treat Broken Hill concentrates, has also closed down. The B.H.P. Company treats the products of several other Broken Hill mines besides its own, but the production of the remaining companies not possessing smelters is sent to Europe (mostly Germany) for treatment.

The Port Pirie metallurgical works belonging to the B.H.P. Company is probably the largest of its kind in the world. At these works a complete series of processes is in operation, resulting in the production of desilverised and refined soft lead, antimonial lead, as well as silver bullion and gold bullion of great fineness. As there is no refinery at the Cockle Creek smelter, base lead bullion is the final product of these works. The following descriptions will, therefore, principally be those in operation at Port Pirie, both because they are more complete, and also because the writer has a more intimate knowledge of them, having been night superintendent and assistant metallurgist there for several years.

ROASTING AND SMELTING.

At Port Pirie, prior to the introduction of the Huntington-Heberlein process, the following was the practice in vogue:—

The sulphide concentrates were roasted in five large Ropp furnaces, with about 5 per cent. of finely-ground amorphous limestone. The concentrates were not sintered before leaving the furnaces. After roasting, the roasted mixture was wheeled out on to a cooling floor. Part of the roasted mixture was then briquetted in three Boyd-White machines, water was added, and the material stirred and worked up into a pug. In the lower portion of the machines it was compressed under heavy pressure into circular discs about $3\frac{1}{2}$ in. in diameter by about $2\frac{1}{2}$ in. thick. The green briquettes were run out on an endless belt conveyer, and removed by boys and stacked in large heaps to dry. During the roasting in the furnace the

CaCO_3 was converted into CaSO_4 , which, on addition of water during the briquetting process, made a very good binder. When dry the briquettes became very hard. They were removed as required, and smelted in the blast furnaces. The three briquetting machines were not capable of treating all the roasted concentrates. The rest was, therefore, put through an ordinary pugging-mill, and wheeled out and filled into tapered moulds. Each block was about 6in. by 4in. by 4in. These pug blocks were allowed to sun dry. The briquetted and pug mixture blocks were smelted with a proportion of low-grade oxidised ore. The pug blocks, more friable than the briquettes, powdered, causing, under the blast then in use—viz., 12 to 16 ounces—a choking and considerable slowing down of the furnaces. Much less trouble was occasioned by using increased blast—viz., 30 to 35 ounces.

The following may be taken as typical of the furnace charges and the slags then produced:—

Kaolin ore	600 lb.	Slag—Pb	1.5 per cent.
Iron ore	1,000 „	Ag	1.0 oz. per ton
Briquettes or pug mixture..	1,500 „	SiO_2	30.0 per cent.
Ironstone	600 „	MnO	13.0 „
Limestone	800 „	CaO	16.0 „
Returned slag	500 „	Al_2O_3	4.5 „
		ZnO	10.0 „
Total	5,000 „		
Coke	525 „		

A small amount of low-grade matter of very variable composition was also produced, containing—

Lead	4 to 30 per cent.
Copper	0.5 to 7.0 per cent.
Silver	10 to 80 oz. per ton

The iron ore was an iron manganese silicious gossan, accounting for the large amount of manganese in the slag. The coke used at that time was mostly Welsh or German. Since then coke made at the company's works at Bellambi, New South Wales, has been almost exclusively used.

After exhaustive experimental trials in 1901, the Huntington and Heberlein desulphurising and sintering process was adopted. Here, as elsewhere, the introduction of this epoch-making process caused a great alteration in the general practice, increased the capacity of the plant, and effected great economy in the production of lead bullion. So great was the increase in capacity that eight blast furnaces did more work than thirteen had previously been able to do.

ROASTING AND SINTERING PROCESSES.

It will be of advantage and increased interest to also consider similar and parallel processes to the Huntington and Heberlein process, and the Carmichael-Bradford process, which are applied to Broken Hill leady products. These processes are—the Kapp-Kunze process, used at Zeehan, Tasmania, and Chillagoe, Queensland; and the Savelsburg process, used in Germany on leady ores; and the McMurtry-Rogers process for copper ores and mattes used at Wallaroo, South Australia. It will be advantageous also to consider the heap-roasting of slimes at Broken Hill.

HUNTINGTON-HEBERLEIN PROCESS.

This process was the pioneer of the pot-desulphurising and sintering processes. It has been used principally with lead ores and leady concentrates, chiefly the latter.

In brief, this process (figure 8) consists in mixing limestone and ironstone with the ore, and also in adding siliceous material if the ore or concentrates do not contain sufficient silica. The mixed material is partially desulphurised in a roasting furnace. Upon discharge, and while still red hot, it is fed into conical or bowl-shaped iron vessels of suitable construction, and a blast of air forced through the charge. Thermo-chemical action takes place, resulting in the ore being desulphurised to a low point, and at the same time the heat generated by the action has been sufficient to fuse or sinter the whole mass, which upon cooling is somewhat like coarse vesicular lava. The total desulphurisation is equal to a good straight-out roasting, while the physical condition of the product is an ideal one, instead of a mass of fines which had previously been the nightmare of blast furnace metallurgists, especially those treating lead ores. Previous to the introduction of this process, and those directly suggested by it, it had been necessary to sinter the fines on a special hearth at the end of the roasting (as originally at Cockle Creek works), causing an appreciable loss of lead and silver by volatilisation and giving a passable product; or the fines were mixed with a small proportion of lime or other binding, and briquetted in machines under heavy pressure, or worked up on a pug mill, moulded, and dried, as at Port Pirie. Both the latter were expensive, costing 4s. to 5s. per ton, and the last-named gave a product which was far from satisfactory.

The Huntington-Heberlein process marks an epoch in modern lead smelting, rendering the treatment of fine lead concentrates easy, economical, and admitting of very high recoveries of value—*i.e.*, lead, silver, and gold. The introduction

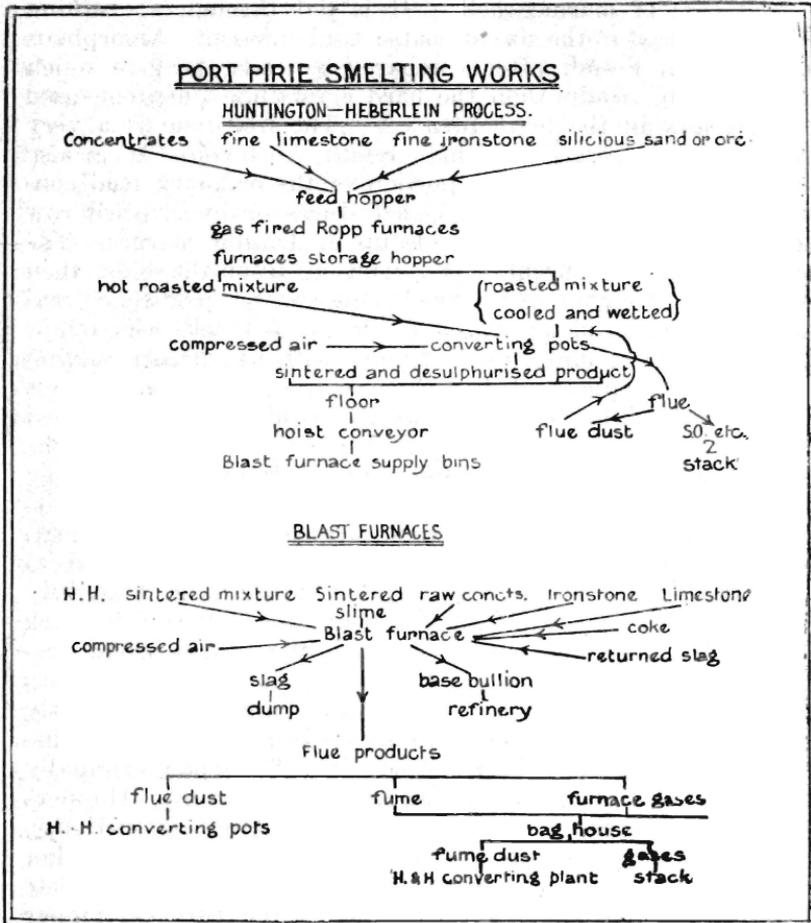


FIG. 8.

of this process has been of inestimable value to the lead industry of Australia and Tasmania. It has been installed at the following plants:—The Tasmanian Smelting Company's works, at Zeehan, Tasmania; the Sulphide Corporation works, at Cockle Creek, New South Wales; the B.H.P. Company's works, at Port Pirie, in South Australia; and at the Chillagoe Mining and Railway Company's reduction works, at Chillagoe, North Queensland; also at the Fremantle Smelting works; the last-named, however, being at present shut down. It was also to have been installed at the incompleated new works at Port Kembla.

The practice at Port Pirie is as follows:—Before charging into the roasting furnaces the concentrates are mixed with amorphous limestone, ironstone, or silicious ore or sand. The amorphous limestone is composed of a loosely cemented mass

of fragments of marine shells. It is put through a crushing mill and reduced to the size of coarse sand, or finer. Amorphous limestone was found, after comparative trials, to give much better roasting results than the hard crystalline limestone used as direct flux in the blast furnaces. The ironstone is a very pure hematite from Iron Knob, South Australia. It is also finely crushed. Sometimes a portion of the ordinary lead concentrates is replaced by raw settled slimes or by crushed raw lead matte. The mixture is made up in definite charges. The proper weight of concentrates is run in from the bins, then the requisite weights of crushed limestone, ironstone, and siliceous ore or sand are run into the same truck, which now holds one charge, and this is tipped without further mixing into the feed hoppers of the Ropp furnaces. The charge is fed continually into the furnace by means of a revolving fluted cylinder at the bottom of the feed hopper. The action of the rabbles is to thoroughly mix the ingredients by the time they have travelled a few feet into the furnace. These Ropp furnaces, five in number, are of very large size—150ft. by 14ft. There are six sets of rabbles—one set turns the material to the right, the next to the left, and each working it slightly forward. It takes about 12 to 16 hours for material to work through the furnace. When coal-fired, there were three fire-boxes to each roaster, spaced along one side of the furnace. The one at the discharge side, or finishing end, is mostly strongly fired, and the other two successively less. These furnaces are now fired with producer gas. They had originally been erected for an ordinary non-sintering roasting. Hoppers at the discharge end were added when the Huntington-Heberlein process was installed, so as to accumulate and keep hot material for charging a converting pot. Formerly a complete charge of hot material was drawn from the furnace hopper for each pot, the blast turned on, the "cooking," or converting proceeding until the operation was finished. Recently an important alteration was made—viz., the lower portion of the charge consists of hot material as formerly, but the upper and larger part consists of roasted material, which has been wetted, and is charged in a wet condition into the pots. This alteration has improved the process. It will be shown later that in the other pot-roasting processes the material is charged cold, and generally in a wet or damp condition. The action commences at the bottom of the charge and around the inlet of the compressed air, and gradually creeps up through the charge to the top. Bars are inserted from time to time to break up blow-hole tubes, which, if left unchecked, would allow the action to reach the surface by a few tubes and die out, leaving much of the charge unacted upon. When a well-appointed mixture is used and properly attended to in the pot sintering, the whole

of about 2oz. pressure is turned on, and as soon as the chips of the mass, except a small amount on the top, is converted into a sintered compact vesicular mass. When the action is complete the blast is shut off, the pot inverted, and the mass tipped out on the ground beneath, more or less breaking it up, cooled by a jet of water, the large lumps broken up, and the whole of the material except the fines sent to the blast furnaces. The fines are fed back into the pots with later charges. The action in the pots is completed in four to six hours. The dust from the roaster, pot converting, and smelter flues is fed in as part of the pot charge.

At the Cockle Creek works large quantities of auriferous pyrites concentrates are worked up in the process. Godfrey furnaces, with fixed rabblers and mechanically-revolving circular hearths, are used for roasting, and large conical cast-iron pots for converting.

Edwards's roasting furnaces and large semi-spherical cast-iron pots are used at both the Zeehan and Chillagoe works. At the latter place the complex cupriferous and zincy lead ores have caused trouble in treatment.

CARMICHAEL-BRADFORD PROCESS.

This pot-roasting and desulphurising process differs in several very essential features from the Huntington-Heberlein process. In it the raw sulphide ores, or concentrates, are mixed with partly dehydrated gypsum, wetted, dried, broken up into lumps, and fed direct without previous roasting into converter pots, in which a small fire has been made in the bottom to start the action, which then continues without any external heat. The product is a well-desulphurised porous sintered mass.

Flour or ground rock-gypsum is dehydrated down to 50 per cent. of its original combined water. It is heated on iron plates at a very low temperature, and then put through a trommel to remove the lumps, which, in the case of the flour gypsum at Broken Hill, are silicious, and forthwith discarded. Three parts of concentrates, slimes, or mixed concentrates and slimes, and one part of partly-hydrated gypsum, are mixed with a small amount of water in a pug mill, and passed through a trommel to ball it into lumps. The partly-hydrated gypsum in the pug mixture combines with more water, and sets into very hard lumps. The surplus water is expelled by drying the lumps on a floor or drying furnace at a low temperature. The mixture is then ready to be fed into the converting pots. Pots suitable for the Huntington-Heberlein process will do equally well for this process, though they may with advantage be made deeper. A shovelful of embers, and then a bucketful or two of chips, are placed in the bottom of the pot, a gentle blast

are well lighted the granulated mixture is run in from a hopper, and the blast raised to about 8 to 12oz. pressure. In about ten to fifteen minutes the action is going strongly, and SO_2 gas coming off freely. During the early stages of converting, the water is driven off, and condenses in the offtake flues. The action commences quickly, is soon going strongly, and continues thus to within a short time of finishing. The converting or cooking is complete in about three to four hours, and is appreciably quicker than in the Huntington-Heberlein process. The sintered material is tipped out on to the floor by inverting the pots. It is then cooled, broken up, and sent to the smelters.

The Carmichael-Bradford process requires very little attention to, and working of, the charge in the pots during converting. This process will readily treat the slime formed in the milling operations. One of concentrates to three of slimes makes an excellent combination for treatment by the Carmichael-Bradford process, whereas a mixture of one of concentrates to one of slimes gives very indifferent results by the straight-out Huntington-Heberlein process.

The percentage of SO_2 in the gas given off in the Carmichael-Bradford process quickly rises, and remains high to very nearly the end of the process, rendering it suitable for the manufacture of sulphuric acid. In this respect it is superior to the Huntington-Heberlein process, as will be seen from the following:—

Carmichael-Bradford Process. Mixture, 1 conc. to 1 slime.				Huntington-Heberlein Process. Ordinary Mixture.			
Time.		SO_2	Charged at	Time.		SO_2	Charged at
10:15 a.m.	6:2 per cent.	10:45 a.m.	..	..	1:1 per cent.
10:25 "	8:3 "	11:0 "	..	..	2:3 "
10:35 "	8:9 "	11:15 "	..	..	3:6 "
10:45 "	10:0 "	11:30 "	..	..	5:7 "
10:55 "	8:8 "	11:45 "	..	..	7:4 "
11:5 "	10:4 "	12:0 noon	..	..	8:8 "
11:15 "	10:4 "	12:15 p.m.	..	..	7:2 "
11:25 "	10:8 "	12:30 "	..	..	8:2 "
11:35 "	11:3 "	12:45 "	..	..	6:0 "
11:45 "	11:3 "	1:0 "	..	..	6:5 "
11:55 "	10:5 "	1:45 "	..	..	6:0 "
12:5 p.m.	10:0 "	2:0 "	..	..	5:3 "
12:15 "	8:8 "	2:15 "	..	..	4:1 "
12:25 "	6:2 "	2:30 "	..	..	3:0 "
12:35 "	3:3 "	2:45 "	..	..	2:8 "
12:45 "	2:3 "	3:0 "	..	..	3:1 "
12:55 "	1:7 "	3:15 "	..	..	2:5 "
1:5 "	8:2 "	3:30 "	..	..	2:1 "
Average	8:2 "	3:50 "	..	..	Finished.
Typical composition of gases—				Average 4.9 per cent.			
SO_3	0.4 "				
SO_2	8.5 "				
CO_2	0.5 "				
CO	Nil				
O	10.6 "				
N	80.0 "				

The plant required is less expensive than for the Huntington-Heberlein process, and where limestone and gypsum are both readily obtained it also has a less working cost per ton.

For localities where gypsum can be obtained at a reasonable cost, the writer considers the Carmichael-Bradford process is superior to the Huntington-Heberlein process both metallurgically and economically for treating leady concentrates, and more especially slimes.

SAVELSBERG PROCESS.

In this process lead ores, mixed with a sufficient quantity of limestone, are fed directly into pots without previous roasting, and desulphurised in one operation by blowing air through them. The reactions are started, as in the Carmichael-Bradford process, by a small amount of carbonaceous lighted fuel placed in the bottom of the pot.

For the best working of this process* it is claimed that the amount of limestone varies with the constitution of the ores, but in general amounts to about 15 to 20 per cent. of the charge. In order that the blowing in of the air may not cause particles of limestone to escape in the form of dust before the action begins, it is necessary to add to the charge a considerable amount of water, say, 5 per cent. or more. This water prevents the escape of dust, and it also contributes to the formation of sulphuric acid, which, by its oxidising action, promotes the reaction, and consequently also the desulphurisation. It is also advised that the chamber (pot) be gradually charged—*i.e.*, in layers—as by this means the reaction takes place more regularly. While the chamber of a pot is being charged, air under low pressure ($2\frac{3}{4}$ to $4\frac{1}{2}$ oz.) is blown through, but when the pot is filled a larger quantity of air at a higher pressure ($11\frac{1}{2}$ to $13\frac{1}{2}$ oz.) is used. Scorification then takes place, a powerful desulphurisation having preceded it. The desulphurisation is completed during the scorification. When the process is completed or the charge “cooked,” the pot is tilted, the fused mass falls out and is broken up into pieces for smelting. A typical charge at Ramsbeck is—

Lead ore	..	..	..	..	100 parts
Quartzose silver ore	..	..	..	..	10 „
Spathic iron ore	..	..	..	..	10 „
Limestone	..	..	..	..	19 „

As in the Huntington-Heberlein process, the thorough mixing of the component parts is essential. The presence of pyrites in the ore is favourable to desulphurisation.

The desulphurisation of a charge is completed in about 18 hours, and requires the allowance of one man per pot. As

* Engineering and Mining Journal, 9th December, 1905.

compared with the Huntington-Heberlein and Carmichael-Bradford processes, as worked in Australia, the pot conversion is slow—viz., 18 hours, as against $3\frac{1}{2}$ to $5\frac{1}{2}$ in the former; while the labour is excessive—viz., one man per pot as against one man per five pots—but this may be due wholly or partly to the greater efficiency and capacity of the more highly-paid Australian workman. A much larger converting plant and staff of men is therefore required.

KAPP-KUNZE PROCESS.

Another of the modifications of the Huntington-Heberlein process has been in operation in Zeehan (Tasmania) and Chillagoe (Queensland) for some considerable time—upwards of four years. It was brought out by Messrs. Kapp and Kunze at Zeehan, where it has been worked under a veil of secrecy. As it has been held by law that lime-roasting is an essential feature of the Huntington-Heberlein process, the modification of Kapp and Kunze should be considered, and is, I believe, claimed to be, a distinct process. This process has, for short, been termed the K.-K. process.

The main features of the process are—the raw lead sulphide or cupriferos lead sulphide ore, broken to 2in. cubes or less, is mixed with a determined quantity of hæmatite or iron gossan. The pots are the same as used in the Huntington-Heberlein, Carmichael-Bradford, &c., processes. A small amount of lighted carbonaceous fuel, as in the Carmichael-Bradford process, is placed in the bottom of the converter pots, a slight blast turned on, and a full charge of mixed ore and ironstone is fed in. As the desulphurising action extends through the mass, the quantity of air is increased. The desulphurisation, scorification, and sintering takes place as in the previous mentioned processes, with a similar ultimate product. About eight hours are required to convert and “cook” each potful.

Direct pot desulphurising is not suitable for ores containing an appreciable percentage of zinc sulphide, as the desulphurisation of the blende is not satisfactory, and causes trouble in the subsequent blast-furnace treatment. Ores containing an appreciable amount of zinc are therefore first roasted without lime, and then cooked with ironstone in pots, as in the Huntington-Heberlein process.

McMURTRY-ROGERS PROCESS.

This process is for desulphurising copper sulphide ores and copper sulphide furnace products.

“The ore may be of any size, $2\frac{1}{2}$ in. gauge down to fine slimes, but preferably the larger pieces should not exceed 1in. gauge, nor is it advantageous that the charge should consist

entirely of slime ore. The charge must contain silica or siliceous material amounting to from 15 to 35 per cent. of silica and from 15 to 25 per cent. sulphur, but the percentage may be somewhat greater or less without very materially affecting the operations of the process, it being also essential that the charge be wetted."*

The upper portion of the pots is more nearly conical than hemispherical, as in the Carmichael-Bradford pots at Broken Hill.

The operation is started by placing some lighted carbonaceous fuel on the bottom of the pots, turning on a slight blast, and then charging in the ore till the pot is about half full, the blast being increased until the ore becomes red, and then adding the balance of the charge.

The blast pressure is usually about 13oz., but ranges up to 20oz. The time to burn a charge varies from eight to twelve hours.

Raw ore containing 20 per cent. sulphur is desulphurised down to about 5 per cent. sulphur. The cost of desulphurising is about 3s. 6d. per ton.

The sintered material is tipped out as a solid lump and broken up as in similar pot processes into suitably-sized pieces for treatment in furnaces.

The process has been installed at Wallaroo, South Australia.

DWIGHT AND LLOYD SINTERING PROCESS.

The *Engineering and Mining Journal* of 28th March, 1908, contains an account of a process for continuous sintering in thin layers. It consists of a pair of circular rims of iron, carrying a set of cast-iron herring-bone grates, the whole forming a drum-shaped structure resting on rollers like a copper converter. The drum acts essentially as an endless conveyer, and is caused to move slowly about its axis by the friction of the drive-rollers. Inside the drum, and occupying the top quadrant of the circle, is a stationary suction-box connected with a suction fan. The moving rim makes an air-tight joint with the edges of the stationary suction-box. The material to be sintered is fed in a thin layer upon the grated face of the drum from an overhead ore-hopper, immediately after which the stream of ore passes under the igniter, which may be a series of gas jets, an oil flame, a charcoal brazier, hot roasted ore, or even hot sinter, whereby the top surface of the ore stream is kindled uniformly across the whole width of the conveyer. The roasting action so begun is maintained and augmented by the streams of air which are sucked down through the moving layer of ore as it passes across the suction box.

* Abstract, Trans. I.M.M., vol. xvi.

When a 4in. layer ore is used (which has been found to be a convenient thickness), about twenty minutes will be required for the sintering action to be completed, and the speed of the periphery is so regulated that the layer shall be completely sintered down to the grate by the time it reaches the far end of the suction-box. The discharging is done automatically by the pointed grizzly frame, which strips the end of the finished sinter cake from the face of the wheel, like bark from a tree.

When the machine is sintering properly the grates do not clog. The best speed for the periphery will depend upon the character of the material under treatment. Thus, with a leady charge, it was about 5in. per minute.

Before being fed to the machine the ingredients of the charge should be thoroughly mixed and moistened to the proper degree. This moisture not only prevents the fresh charge from sifting through the grate bars, but greatly promotes the activity of the sintering process.

It is claimed that a 50 per cent. lead concentrate may be sintered, and contain less than 3.5 per cent. sulphur. The cost is said to be lower than for pot roasting.

HEAP ROASTING OF SLIMES.

The B.H.P. Company runs out its settled slimes in a semi-fluid condition as a layer about 6in. to 1ft. thick over the ground, and it is left for several days to dry. While still in a plastic condition, the mass is cut with spades into rectangular blocks about 6in. across, and left to dry into hard lumps containing about 1 per cent. of moisture. The lumps are loaded into trucks and railed to a spot about five miles out of the town, and here they are built into heaps and roasted. The heaps are about 20ft. wide, 7ft. high, and about 200 to 250ft. long. A central flue, to within a few feet of either end, is built of loose bricks along the ground, and side flues about 10ft. apart from the centre flue to the sides. The lumps are packed into heaps of the above dimensions, with the sides battered back at about 60 degrees. The fines and small lumps are mixed in a pug mill, and used to plaster the sides and ends of the heaps, filling up all spaces and cracks, the surface being smoothed off. Wood fires are lighted in the side flues until the action has got well started. They are then discontinued, and the supply of air is regulated. The fire reaches all parts of the heap in two days. The heaps burn for about eight days. The central portion of the heap has now sintered into a black porous mass, while the outer strip is of brownish, half-roasted material, which is built into the next heap. When cool, the heap is picked down, the mass broken up, loaded on to railway trucks, and sent to the metallurgical works at