ducers and regenerative chambers, and silica brick for those parts of the furnace directly exposed to the action of the flame. The mortar for the latter brickwork having the following composition :—

Moist	=	·60	$Ca\ O$	=	2·88
Water comb	=	1·40	$Fe_2\ O_3$	=	1·30
$Si\ O_2$	=	89·14	$Mg\ O$	=	·68
$Al_2\ O_3$	=	3·92	Na_2O, K_2O	=	·32

The whole of the material inclusive of the sand used for the furnace hearth, and known as Belgian sand, was imported from England, a procedure which probably will be discontinued in the future, at least with regard to the sand, which doubtless could be obtained locally.

As to whether the fireclay or silica bricks used in the future will be of English or Colonial make depends on the quality of the Colonial raw material for producing both classes of brick ; and secondly, upon the Colonial skill in making a good brick from a good material.

It is by no means an uncommon occurrence for a good refractory clay to make a poor fire brick through a want of skill and knowledge on the part of the maker.

The supply of imported stoppers for the ladle having run out, Mr. Sandford has been obliged to fall back on locally made stoppers, and these, so far, have not come up to the standard of the English article.

The furnace is worked from two doors, one being at the end opposite the gas and air ports, and the other at the back opposite the tapping hole as shown in photograph II.

These doors are composed of silica brick set in a strong iron casting, and are raised and lowered by means of a lever from which they are suspended by a chain, their weight being almost counter-balanced by a weight suspended from a chain at the other end of the lever.

The Process.

The two main processes carried out in the Siemens furnace, are, as already mentioned, the acid process for the treatment of stock free from Phosphorus and the basic process for the treatmentof stock containing Phosphorus.

There are in addition two modifications of both these processes, viz : the pig and ore process, and the pig and scrap process.

In the pig and ore process the initial charge to be converted into steel consists almost entirely of pig iron, and of a small amount of steel scrap, which, as a rule, consists of the waste from a bar or plate mill which works up the steel ingots from the Siemens plant, or, as it is generally termed, the melting shop.

When the charge is melted down, the elimination of the metalloids is effected partly by the oxidising action of the flame, but mainly by the additions of a pure iron ore, an ore commonly used in Great Britain for this purpose, being the pure Spanish hematites.

By the combined action of the oxygen in the gases, and the oxygen of the ore, the impurities present in the molten bath of pig iron, which in the acid Siemens process comprise manganese, sulphur and carbon are oxidised and eliminated in the foregoing order:—The oxides of manganese and sulphur passing into the slag while the carbon is oxidised to carbon monoxide and escapes from the furnace with the products of combustion. In the basic Siemens process, phosphorus, as well as the elements already mentioned, has to be eliminated from the bath, and in order of elimination the phosphorus leaves the bath last and enters into combination with basic additions of limestone, which, in the basic process, are added to the furnace charge as well as iron ore. Sulphur, like phosphorus, if present in the pig iron is not eliminated in the acid, but is in the basic process.

The heat generated by the combustion of the manganese, sulphur and carbon, etc., which is an all important factor in the Bessemer process of steel making is of but little consequence in the open hearth process, the necessary heat being obtained from an external source, whereas in the Bessemer process the very impurities to be eliminated serve as the fuel essential for the carrying out of the process.

In the pig and scrap modification of the open hearth process, the charge to be converted into steel, comprises, for the major part, steel scrap, a very ordinary proportion, being seventy-five per cent. of scrap and-twenty per cent. of pig iron. Such a charge, owing to its great preponderance of scrap, contains a smaller percentage of metalloids to be eliminated than the charge of the pig and ore process, and consequently when it is melted down there is no need to have recourse to the addition of iron ore, as the ordinary action of the gas is sufficient in itself to eliminate the the smaller proportion of metalloids. As to which modification of the open hearth process is to be adopted, whether the pig and ore or the pig and scrap, depends upon existing conditions.

In a locality with cheap pig and a scarcity of scrap, the process to be adopted is the pig and ore process, whereas the pig and scrap process should be adopted in a locality where scrap is plentiful and pig iron scarce. The latter condition holds at Lithgow.

In purchasing old wrought iron scrap for the purpose of re-rolling the same at his mills into bars, angles, sheets, etc., Mr. Sandford accumulated large quantities of steel scrap, such as rails, steel plate clippings, car wheels, tires, springs, etc., to the amount of some thousands of tons. Such material it was not possible to roll out in the same way as wrought iron scrap, and the only method of dealing with it was by working it up in a Siemens Open Hearth furnace with a certain proportion of imported pig iron of Bessemer grade.

This eventually Mr. Sandford decided to do, especially as there exists a demand, which same demand is continually growing, for certain soft steel shapes, a demand which hitherto he had met by importing and working up American steel billets.

As the outcome of this decision is the small Siemens furnace, the erection of which was commenced in 1899 and which started working on April 1st of the present year. To this furnace is allotted the task of working off the accumulations of hard, medium, and soft steel scrap and the production of a soft steel, containing if possible, no more than ·1 per cent. of carbon.

The pig iron used in the process and which constitutes 25 per cent. of the charge is free from phosphorus and sulphur, and a sample of the iron from analysis gave the following composition :—

Carbon	=	3·79	per cent
Silicon	=	3·64	„ „
Manganese	=	·21	„ „
Sulphur	=	·06	„ „
Phosphorus	=	·056	„ „

The working off of a charge is as follows :—

The amount of pig iron for a charge having been weighed out on a small platform scales, it is charged into the furnace, and when it has been all charged a certain amount of the steel scrap is added, and the remainder from time to time as the charge melts, the time elapsing from the commencement of the charging of the pig to the completion of the charging of the scrap being about three hours.

The following is the composition of a typical charge :

		Tons	Cwts.
	Barrow Pig Iron	1	1
Steel Scrap.	Rails	0	10
	Fish Plates	1	3
	Plate Clippings	1	6
	Springs	0	4
		4	4

During the melting down stage practically all the manganese present in the charge and almost all the silicon is oxidised. After the melting down stage the boiling stage commences so-called from the bubbling action which takes place all over the surface of the bath of metal and which is due to the oxidation of the carbon, carbon monoxide, being formed which escapes from the metal. To hasten the elimination of the carbon, a couple of shovelfuls of iron ore added during this stage the following reaction occurs.

$$Fe_2\,O_3 + 3C = Fe_2 + 3CO$$

which results in the reduction of iron from the ore and in the formation of carbon monoxide.

Phosphorus and sulphur if present are not eliminated, but remain in the bath of steel, and so only that steel must be used which is free from these two elements.

Towards the end of the operation, samples of metal are taken out from time to time in a small iron ladle, chilled in water and broken, and the softness of the metal judged from its fracture.

When the metal is practically free of all impurities the recarburizer, which has been weighed out and heated, is added. The amount for the charge of four tons four cwts. already specified was two quarters twenty-five pounds of ferromanganese of the following composition :

Manganese	=	80	per cent.
Carbon	=	6·7	„ „
Iron	=	11·82	„ „

The object of the recarburizer is twofold :

(1.) To render the metal quiet in the moulds and so to ensure sound castings.

(2.) To give to the finished steel the requisite amount of carbon, for it is this element which gives to different classes of steel their distinctive physical properties, and other things being equal, it is known that the capacity of the steel to fulfil the requisite physical specifications depends on the percentage of carbon it contains.

In explanation of the first object it may be stated that soft metal, that is, metal from which practically all the carbon has been eliminated contains a large amount of occluded oxygen, which, if not eliminated, would, in casting, give rise to unsound ingots. The manganese of the recarburizer by combining with the oxygen and forming oxide of manganese which enters the slag effects this required elimination, whereas the carbon in the ferromanganese brings the carbon up to the percentage required in the finished metal.

There are two methods in vogue for the addition of the recarburizer, one being to shovel it into the furnace on to the soft metal and to tap the charge immediately afterwards. The other method is to tap the furnace first and to shovel the recarburizer into the ladle as the steel is falling into it.

The advantage of the first method is the certainty of the recarburizer being well dissolved and mixed with the metal, and in consequence the production of a uniform metal. The disadvantage is that during the time which elapses between the charging of the recarburizer into the furnace and the tapping of the charge, carbon and manganese are being eliminated, and such perfect control over the composition of the metal as regards carbon and manganese contents is not as possible as in that case in which the recarburizer is charged into the ladle. The advantage of recarburizing in the ladle is that more perfect control over the final composition of the metal is attained, the disadvantage being the uncertainty of perfect mixing which in a large charge of twenty to thirty tons is not likely to occur, but which may happen in a small charge of three to five tons, especially if the metal is at all cold.

The practice at the Eskbank works is to charge the ferromanganese, broken up into small pieces into the furnace, and to tap the charge immediately into the ladle. The metal runs from the tapping-hole down an iron launder or gutter lined with fire clay, and thence discharges into the ladle.

The moment the charge is tapped and the furnace empty, the hearth is examined to see if it is sound, and if any holes are found these are repaired with sand and the furnace is ready for a fresh charge. The time of working off a charge varies, but this is now done in a shorter time than previously. Three charges in twenty-four hours is the best work yet attained, although similar furnaces in England and on the Continent working approximately the same charges of one quarter pig and three quarters scrap put through four charges in the twenty-four hours.

Casting the Steel.

The ladle into which the metal from the furnace is tapped is supported on a wheeled-carriage, which runs upon a track of standard gauge as shown in photograph III. This track as shown in the photograph is about eight feet below the level of the furnace floor, and runs parallel to and about four feet in front of the furnace.

The ladle as shown in Fig. VII. consists of $\frac{1}{2}$ inch rivetted plates lined with a three inch course of fire brick. Its height is three feet nine inches, and diameter at the top three feet six inches, and at the bottom two feet eight inches.

The metal is tapped or teemed through the nozzle at the bottom of the ladle into the moulds. This nozzle is closed by a fire clay stopper, which can be raised or lowered by means of an iron rod protected by fire clay pipes.

The metal from the ladle is teemed into moulds placed underneath the ladle and in the casting pit.

The casting pit which as seen from photograph III, lies between and beneath the rails carrying the ladle carriage, is a rectangular brick-lined pit thirty feet long, four feet wide, and five feet deep.

In this pit are placed the moulds in a line directly under the nozzle of the ladle. The moulds used are of cast iron rectangular in cross section with rounded corners, some being three feet six inches high and others four feet ten inches. They widen from above downwards having a six inch side at the top and seven inches at the bottom. In teeming, the ladle is brought over the first mould and the stopper raised. The metal runs through the nozzle into the mould, and when the latter is nearly full the stopper is lowered, and the ladle run over the next mould, when the operation is repeated, and so on until all the metal is tapped. On top of the metal in each mould, as soon as the ladle passes to the next mould, sand is thrown on and the top is covered over by an iron plate held in place by a bar passing through rings on the opposite sides of the mould and wedges hammered in between the bar and the plate.

The original arrangement for teeming the metal from the ladle into the moulds was that as shown in Fig. VIII. In this the metal runs down a central tube or pipe lined with fire clay and branching out at the bottom into four channels, each one communicating with three moulds. The metal in this arrangement is teemed down the central pipe, passes along the horizontal ones, enters and fills the mould from below. This method of casting the metal from below is stated to give sounder casting than the method at present in use and already described. The reason for its discontinuance was due to the fact that the metal solidified in the tubes, preventing the castings being made, and consequently the entire charge was lost. The fault was probably due to the melters not having the metal hot enough when tapping.

The moulds are set in the casting pit by means of a Priestman travelling crane running on a track parallel to the track for the ladle. The crane also serves to strip the ingots of the moulds and to transfer the former to cars which carry them to the rolling mill, where the ingots are annealed and rolled into angles, bars, sheets, etc. The furnace, casting pit and crane are covered by an iron roof with a span of seventy feet, and a height at the pillars of twenty-one feet with a length of sixty feet.

The general arrangement of furnace casting pit travelling crane is shown in photograph IV. In addition to plant described, there is a second ladle, a coal-fired reverbatory furnace for heating the sand used in repairing the hearth and a boiler for supplying the steam to the producers.

Analytical Work.

The analytical work carried out in connection with the process comprises a carbon determination by the colour method for each charge of finished metal tapped from the ladle. The sample for analysis is taken in a small ladle placed under the stream of metal teeming into the moulds. Drillings for analysis are taken from this sample. To check the composition of the steel a complete analysis is made weekly from such a sample, the elements determined being carbon, sulphur, silicon, manganese and sulphur.

In addition to the foregoing, analyses are made of consignments of pig iron with a view to determining the percentages of sulphur and phosphorus, and of the ferromanganese used as the recarburizer and any special analyses which may from time to time be required during the ordinary working of the furnace.

Labour.

The number of men employed is as follows:

6 furnace men (3 for each 12 hours shift)
4 pitmen
2 cranemen
2 charge wheelers
1 man at producers
1 boy
1 labourer
——
17

The number of shifts worked is two in twenty-four hours, and after the charge is tapped on Saturday morning a fresh charge is not made until Monday, the fires being kept up, meantime, in the producers.

Furnace Record.

Regarding the record of the furnace, it started working on April 7th of the present year and stopped on October 11th in order to clean out and effect repairs in the regenerators. During that period two hundred and forty-one charges were worked off with a production of seven hundred and seventy-eight tons of ingot steel.

The amount of steel produced in September was two hundred and fifteen tons, the furnace taking sixty charges and this is the best record for any one month since the start.

To produce one hundred tons of ingot steel thirty-one tons of pig iron and seventy-eight tons of steel scrap were employed, making a total of one hundred and nine tons, and in addition nineteen hundredweights of ferromanganese as recarburizer.

No record was taken to show the amount of coal consumed in the producers per ton of steel produced.

In producing the one hundred tons of steel already referred to, the total amount of coal used at the steel plant amounted to sixty-one tons large coal, six tons slack coal. These figures include the coal used for the producers, for heating the ladle before tapping the metal, for the sand furnace, for the travelling crane and for the boiler generating steam for the steam blast in the producers.

New Processes.

So far in dealing with the Siemens Open Hearth furnace and process, the original type of furnace and improved modification of this type have only been referred to.

The processes dealt with as carried out either in the original type of furnace or in the improved modifications are those old standard processes—the pig and ore process and the pig and scrap process. So long as these two processes are continued in the way already described, the product of the open hearth furnace will be a metal superior in quality to Bessemer metal and of a higher cost. By modifications in design, such as the increase in size of the furnaces, the introduction of tilting furnaces, and of mechanical devices for charging, and finally by placing the producers alongside of the furnaces the cost of steel production by this process is considerably reduced, but not brought down to the same low cost of production as Bessemer metal.

Hitherto the sphere of operations of the two processes has been pretty clearly defined. To begin with, a pig iron containing over one-and-a-half per cent. of phosphorus must of necessity be treated for the manufacture of steel by the basic Bessemer process. A pig iron containing a phosphorus content between ·1 and 1·5 per cent must be treated for the manufacture of steel by the basic Siemens process.

Finally pig iron containing less than ·1 per cent of phosphorus can be treated for the manufacture of steel by the acid Siemens or acid Bessemer process.

Now, regarding the manufactured steel, the Siemens steel is undoubtedly of better grade than the Bessemer, and is now being used for all purposes in which a perfectly reliable metal is the first consideration, and cost the second, such purposes being for ship and bridge building, etc.

Bessemer steel, for reasons not yet perfectly understood, is not so reliable as Siemens steel, which in the case of steel above all other materials is a very serious fault. However, as such steel can be produced cheaper than Siemens steel as manufactured by the processes already described, in view of its cheapness it is able to hold its own, and is the sole steel used in the manufacture of rails.

If it were possible to produce open hearth steel of open hearth quality at a cost not exceeding the cost of Bessemer steel, the supremacy of the Bessemer process would be seriously threatened.

If such were possible, the Open Hearth process would have a second advantage over the Bessemer process in being less unwieldly.

By unwieldly, as applied to the Bessemer process, I mean that its production is enormous, and an enormous production needs an enormous market. There is no way of diminishing the output to meet a moderate demand, for in doing so the cost of production goes up, and the one great advantage of the process is lost. Its unwieldiness lies in its big production.

On the other hand, a Siemens Open Hearth plant can be made of any capacity suitable for the demand, and a plant of a moderate capacity can be erected to meet a moderate demand.

To return to the main consideration, two radical alterations in the Siemens Open Hearth process have been introduced and carried out on a large scale during the last two or three years, and these are the Talbot Continuous Open Hearth process and the Bertrand-Thiel process.

In both processes an economy over the old processes already described, and still almost universal, is effected by charging into the furnace, or rather tapping into the furnace, molten pig iron from the blast furnace, mixer or cupola. Both processes in this respect are similar to the Bessemer process in which molten pig iron, or, as it is termed, direct metal, is run into the converter. Considering from this point the Talbot process, when the charge, which is about eighty tons, and held in a tilting furnace, is refined and converted into steel, the furnace is rotated and a portion of the steel is run out through the tap hole into the ladle, where it is recarburized in the ordinary way.

The remainder of the charge which is left in the furnace—about 75 per cent. of the whole—receives charges first of iron ore to enrich it from an oxidising point of view, and lime to fix the phosphrous when oxidised. After melting an addition of molten pig iron is poured into the furnace. A violent reaction ensues between the oxygen of the finely divided ore already added, and the metalloids contained in the pig iron which latter are eliminated, the phosphorus, sulphur, etc., being retained by the lime, and the carbon burnt off as carbon monoxide. The action is intense, and the yield of material high, for, for over one hundred tons of pig iron charged, there results one hundred and five to one hundred and six tons of ingots, the balance being reduced by the metalloids from the iron ore. About one quarter of the finished metal is tapped, a further addition of iron ore is made and then of pig iron as before, and the process works continually.

The production of an eighty or one hundred ton furnace amounts to six hundred to seven hundred tons per week. The furnace has a basic lining as also is the case with the furnaces in the Bertrand-Thiel process; the two processes treating a pig iron containing more than ·1 per cent of phosphorus.

Messrs. Bertrand and Thiel proposed that the refining of the pig iron, especially phosphoric material, should be conducted in two or more furnaces, that the liquid iron should be poured into the first furnace, and taking advantage of the fact that phosphorus could be removed at a low temperature, iron ore and lime were rapidly added to the molten charge. A violent reaction ensued between the oxygen