Comparison of Bessemer and Open Hearth Processes.

Quality of Metal Produced.—The first consideration is the question of quality, and here it must be admitted that acid processes have the advantage over basic processes working under ordinary conditions, as, assuming care is taken to select suitable pig-iron, the risk of producing high Phosphorus steel in the acid processes is at once eliminated, whereas, however great the care taken, the removal of the Phosphorus in the basic processes depends upon the skill and attention of the men, and there is always the possibility that the metal may not be dephosphorised to the required extent. In the case, too, of the manufacture of rails, or other fairly high Carbon steel in the converter, there is the additional risk of rephosphorisation from the slag on adding the recarburising material, even when every precaution is taken. With dead soft steel this danger exists in a smaller degree. In respect to removal of other impurities, the acid processes offer no advantages over the basic, as, in the removal of Sulphur, the advantage lies with the basic process, in which removal, if somewhat erratic, does frequently take place.

With regard to the open hearth process, where steels of different grades are required, with Carbon varying from ·100 to ·70 or 1·00, the acid process has again the undoubted advantage over the basic open hearth, as in working ordinary phosphoric pig-iron, recarburisation would have to be effected outside the furnace by some recarburising process, which does not enable the same control to be maintained as when it can be done in the hearth of the furnace. In the special case of working hematite iron in a basic furnace, the conditions are different, and we have the advantage of the pure iron used in acid furnaces, with the additional advantage that even the small percentages of Phosphorus originally present would be greatly reduced, and, consequently, an exceptionally pure material can be made.

The basic open hearth for treating hematite or low phosphoric pig-iron, although extending, has not come into general use, but the process is practically confined either to high phosphoric pig-iron, or pig-iron containing just too much Phosphorus for use in the acid open hearth. The reason for this is largely due to the fact that the majority of our English plants working the acid process have not blast furnaces in connection with their steel plants, and consequently cannot take molten mixer metal, but are confined to cold pig-iron, and in most cases this is high in Silicon, and would be very destructive of the furnace bottoms. Under conditions where hematite iron could be desiliconised in a mixer, there can be little doubt that the basic open hearth would be much more economical than the acid open hearth working cold materials, especially when the increased yield is taken into consideration. The improvement in the quality of the steel, especially in respect to low percentage of Phosphorus, would be undoubted, and there seems every reason why basic furnaces should be used in preference to acid, provided molten metal is obtainable, and it is probably only a question of time for them to be generally adopted.

Comparing the quality produced in the open hearth, whether acid or basic, with that of the Bessemer processes, there can be no doubt that the former produces a more regular and reliable material. In the first place, the operations are under greater control. Samples can be taken at repeated intervals, and examined if necessary, both chemically and mechanically, and the working of the process modified to produce the desired result. There is also far less danger of over-oxidation. That the quality of open hearth steel is, for the same class, superior to Bessemer, is confirmed by the fact that engineers, as the result of experience, always prefer it, and are prepared to pay a higher price for it. For high Carbon steels which have to conform to rigid specifications, the acid Siemens is almost exclusively employed, as experience has shown that it is extremely difficult to get the exact Carbon percentage specified by the other processes. Exception to this may be made in a few cases of small Bessemer plants in Sweden and this country, working under special conditions as to the regularity and quality of their pig supply, and the smallness of their charges; but, speaking generally, the statement is correct.

Yield of Metal.—Here the open hearth processes have a considerable advantage over the Bessemer. The average yield of an acid Bessemer plant making rail steel will vary from about 86 to 88 tons of steel ingots for every 100 tons of metal (including pig, scrap, spiegel, &c.) used; and a basic Bessemer will yield only about 83 tons of ingots, whereas the acid open hearth, working with cold pig-iron and scrap, will yield about 97, and the basic about 95·0 tons of ingots per 100 tons of metal charged into the furnace. One reason why the yield in the basic processes is lower than the acid, is that the chemical loss due to presence of Phosphorus and more Manganese is greater. In modern basic open hearth practice where mixer metal of regular quality is taken molten to the basic open hearth furnace the yield should be at least 100 tons of ingots for each 100 tons of pig and scrap charged and in some cases will average as much as 102 to 103 tons.

Cost of the Acid and Basic Processes.—Both the labour costs and the costs as regards renewals of linings, repairs, and general refractories, must always be higher in the basic than in the acid processes; but against these disadvantages must be put the lower cost of pig-iron and scrap and the value of the basic slag produced. For the same size of plant, on the other hand, the output of the acid processes will be greater.

Comparison as to Cost.—It is extremely difficult to give fairly comparative costs, as prices at the same time vary very much in different districts, especially the price of scrap. At normal times, however, in the same district, the differences in price of hematite pig-iron and good basic iron will vary from 6s. to 8s. per ton in favour of the latter, although common phosphoric pig-iron, as used in some Bessemer plants, may sometimes be obtained for 10s. per ton less than hematite. It is, however, doubtful if there is any real advantage in using an iron of this class, as extra waste, &c., probably more than neutralises any gain in price. The difference in price of selected scrap suitable for open hearth acid work, and the miscellaneous wrought-iron and steel scrap which can be used in the basic open hearth will, in many cases, be 10s. per ton, and may be taken generally as at least 5s.

Taking the above as roughly representing the difference in the cost of materials to-day with present prices of labour and fuel, after allowing for all incidental and establishment charges, there is little difference in the cost of producing ingots by the various processes.

After crediting basic steel with the value of slag produced per ton of ingots, provided sufficient scrap can be obtained to work 30 per cent. in the charges, ingots can probably be produced more cheaply by the basic Siemens process than by any other.

The difference in cost of production by the acid and the basic Bessemer is so little, that it is almost impossible to say which has the advantage, although it is probable that the basic is slightly the cheaper.

The acid Siemens costs of production are probably a little higher than any of the others, although they are only slightly so, and, provided a good supply of scrap equal to 30 per cent. of the charges can be obtained, the difference is very slight.

Any slight variation in price of scrap, of course, at once alters the cost of production, and this is one of the difficulties attending Siemens work, in many districts it being almost impossible to get a good supply of high-class quality in sufficient quantity.

The costs of production in the modifications of the Siemens processes, such as the Talbot and Bertrand-Thiel processes, are difficult to obtain. In the case of the Bertrand-Thiel no entire plant has been designed to carry out the process under the best conditions, and the works using the process are working under disadvantages, but, in view of the fact that it has not been more generally adopted, presumably the advantages over the ordinary open hearth process cannot be so great as was anticipated. The Talbot process is now in use at various works in England and America, and appears to be making steady, if somewhat slow, progress. Judging from the small amount of reliable information available, the costs appear to be distinctly lower than in the ordinary open hearth working under the same conditions, especially when low Sulphur iron is available, and the chief objection to the process is the cost of the installation, which probably has been the principal reason why it has not been more generally adopted. At first the cost of repairs to the ports and furnaces was very heavy, but this has been considerably reduced by gradual improvements in construction.

Recently the large Witkowitz Steel Works decided to abandon the Duplex process, which had been in operation at their works for a number of years, and after a most careful investigation of the various modifications of the Basic process working on the Continent, in America, and England, were still somewhat in doubt which process was the most suitable under their special conditions. They, therefore, decided, before putting down a complete plant, to carry out what may be regarded as a unique metallurgical experiment and erect a special plant consisting of a 300-ton mixer, three fixed 50- to 60-ton furnaces, one Wellman 60-ton tilting furnace, and one 200-ton Talbot furnace. The Talbot furnace was designed so it could be used as a mixer should this process prove unsatisfactory, and if it were decided to use this process the fixed furnaces could be utilised for melting the large quantities of scrap produced in their different mills.

This plant was operated for nearly a year, the greatest care being taken to weigh the raw materials used and the finished products obtained, and also to test the different steels for their suitability for the various purposes required. For six weeks a special staff of engineers was employed night and day to check all the weighings in and out, and make sure that furnace scrap, etc., from the different furnaces was credited to the right furnace. The mixer was used largely as a storage for molten metal, no refining apart from desiliconising being done. The following table shows the average composition of the pig-iron and mixer metal used :—

Average Analyses.

(a) Pig Iron.				(b) Mixer Iron.			
Mn per cent.	Si per cent.	P per cent.	S per cent.	Mn per cent.	Si per cent.	P per cent.	S per cent.
1·67	0·69	1·08	0·06	0·94	0·21	1·07	0·04
1·57	0·69	1·51	0·07	0·97	0·25	1·48	0·04
1·56	0·56	1·74	0·07	0·86	0·17	1·67	0·03

It will be noted that two kinds of iron were used, one containing about 1·1 per cent. and the other 1·5 to 1·7 per cent. Phosphorus.

The amount of steel produced was from 800 to 1,000 tons per twenty-four hours. The tilting furnaces were designed with fixed interchangeable port-blocks on the Friedrich system, and the tilting section rotated about an axis passing through the centre of the two gas ports.

The results of these very extensive experiments were given in a very exhaustive paper by Dr. Friedrich Schuster before the Iron and Steel Institute in May, 1914, and the following summary of his conclusions, and the tabular statement, giving a comparison of the working costs of the different processes, is taken from his paper. Dr. Schuster particularly emphasised the fact that the conclusions drawn apply strictly only to the Witkowitz conditions, and that different results may be obtained where working under different conditions:—

Dr. Schuster's Conclusions.

"1. By using a mixer (capable of being heated), and carrying out but a small amount of refining in the same, the production of the steel furnaces supplied by it can be increased by about 30 per cent.

"2. The quality of steel produced is, both physically and chemically, independent of the type of furnace employed.

"3. The yield is influenced by (a) the pig-iron employed, and (b) the ratio of scrap to mixer iron and pig-iron respectively; and such yield is practically the same whenever the same conditions are observed in furnaces of different types.

"4. The Talbot furnace is the type most adaptable to the working up of pig-iron of varying composition, and to changes, within fairly wide limits, in the amount of scrap added.

"5. In the Talbot furnace, pig-iron of the lowest to the highest phosphorus content can be worked up without deteriorating the quality of the steel, the decline in output with pig-iron rich in phosphorus being smaller than in the case of other types of furnace.

"6. Although the actual first cost of the Talbot furnace is appreciably higher than that of a tilting furnace of small capacity, or of a fixed open hearth furnace, these costs, calculated on the daily tonnage produced, work out most favourably for the Talbot furnace.

"7. The yield of metallic iron from the oxide additions (ore and cinder) is higher in the Talbot furnace than in other types.

"8. The slag produced in the Talbot furnace is (owing to the concentra-

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Comparison of Costs.

Wellman Process (New Steelworks, Witkowitz).			Open Hearth Process (New Steelworks, Witkowitz).			Duplex Process (Old Open Hearth Works, Witkowitz).		
1·7 per cent. 104·4 ,, .. 175 tons.			1·7 per cent. 101·1 ,, .. 300 tons.			0·4 per cent. 88·0 ,, 3·1 ,, 514 tons.		
Weight per Ton of Yield.	Shillings per Ton of Yield. Item.	Total.	Weight per Ton of Yield.	Shillings per Ton of Yield. Item.	Total.	Weight per Ton of Yield.	Shillings per Ton of Yield. Item.	Total.
Mixer Costs. 837 114 7	3·45 36·82 6·38 1·40 ..	48·05	Mixer Costs. 738 244 7	2·57 32·47 13·66 1·40 ..	50·10	1068·1 56·1 9·0 0·7 1·3	47·0 3·14 } 2·20	52·34
958 With Mixer Without Mixer	(50·15) (45·42)		989 With Mixer Without Mixer	(50·66) (46·97)		1135·2	(46·11) (44·60)	
165	4·62		147	4·12		27·2	0·76	
41	0·61		27	0·41				
		5·23			4·53			0·76
		53·28			54·63			53·10
116	1·39		109	1·31		78	0·93	
		1·39			1·31			0·93
260	1·15 4·94		307	1·37 5·84		267	5·07	
		6·09			7·21			5·07
	2·45			2·52			2·85	
		2·45			2·52			2·85
	1·71			1·62			2·23	
	2·40 0·50			2·46 0·50			5·52 0·50	
		4·61			4·58			8·25
		67·82			70·25			70·20
250 (13 p. cent.)	3·50		210 (14 p. cent.)	3·20			0·52	
		3·50			3·20			0·52
		64·32			67·05			69·68
		18·90			20·08			25·08
		107·7			112·3			116·7

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TABLE XXXV*a*.—Comparison of Costs.

		Talbot Process (New Steelworks, Witkowitz).			Wellman Process (New Steelworks, Witkowitz).			Open Hearth Process (New Steelworks, Witkowitz).			Duplex Process (Old Open Hearth Works, Witkowitz).		
Phosphorus in pig-iron (approximate),		1·7 per cent.			1·7 per cent.			1·7 per cent.			0·4 per cent.		
Yield,		105·2 ,,			104·4 ,,			101·1 ,,			88·0 ,,		
Loss of balance,		..			..			..			3·1 ,,		
Daily production,		295 tons.			175 tons.			300 tons.			514 tons.		
	Cost per Ton. Shillings.	Weight per Ton of Yield.	Shillings per Ton of Yield.		Weight per Ton of Yield.	Shillings per Ton of Yield.		Weight per Ton of Yield.	Shillings per Ton of Yield.		Weight per Ton of Yield.	Shillings per Ton of Yield.	
			Item.	Total.		Item.	Total.		Item.	Total.		Item.	Total.
Charge—		Mixer Costs.			Mixer Costs.			Mixer Costs.					
Basic pig-iron,	44·0	878	3·80		837	3·45		738	2·57		1068·1	47·0	
Scrap,	56·0	66	38·63		114	36·82		244	32·47		56·1	3·14	
Ferro-manganese,	200·0	6	3·70		7	6·38		7	13·66		9·0		
Ferro-silicon,	..	..	1·20		..	1·40		..	1·40		0·7	2·20	
Spiegeleisen,	..	..	..	47·33	..	..	48·05	..	..	50·10	1·3		52·34
Cost per ton of charge,		950 With Mixer	(49·82)		958 With Mixer	(50·15)		989 With Mixer	(50·66)		1135·2	(46·11)	
,, ,, scrap and pig,		Without Mixer	(44·84)		Without Mixer	(45·42)		Without Mixer	(46·97)			(44·60)	
Oxides—													
Swedish ore,	28·0	160	4·48		165	4·62		147	4·12		27·2	0·76	
50 per cent. manganese ore,	42·0												
Cinder (own),	15·0	44	0·66		41	0·61		27	0·41				
,, (bought, slag),	17·0			5·14			5·23			4·53			0·76
Total ore and metal,				52·47			53·28			54·63			53·10
Lime,	12·0	108	1·30		116	1·39		109	1·31		78	0·93	
Fluorspar,	25·0			1·30			1·39			1·31			0·93
Fuel—													
Cost of gasifying,			0·98			1·15			1·37				
Coal,	19·0	221	4·20		260	4·94		307	5·84		267	5·07	
Coke, graphite, wood, etc.,				5·18			6·09			7·21			5·07
Refractory Material—													
Chrome ore,	65·0												
Refractory material for furnace,			1·40			2·45			2·52			2·85	
,, ,, working,													
Dolomite, tar, including wages,				1·40			2·45			2·52			2·85
Various Expenses—													
Steam, gas, electricity,			1·71										
Tools, stores, and spare parts,						1·71			1·62			2·23	
Other operations, wages, material,													
Direct wages, salaries, bonus,			2·28			2·40			2·46			5·52	
Ingot moulds,			0·50			0·50			0·50			0·50	
General, royalty, depreciation, etc.,				4·49			4·61			4·58			8·25
Gross cost of production,				64·84			67·82			70·25			70·20
Less—Value of slags,	20·0 3·0 23·50 2·50	187 (19 p. cent.)	5·15		250 (13 p. cent.)	3·50		210 (14 p. cent.)	3·20			0·52	
Steam and waste heat utilised,				5·15			3·50			3·20			0·52
Net cost of production,				59·69			64·32			67·05			69·68
Cost of conversion (referred to 1 ton of scrap and pig),				14·85			18 90			20·08			25·08
Comparative cost of production,				100			107·7			112·3			116·7

tion of the phosphoric acid when using pig-iron high in phosphorus) more valuable than in other types of furnace; and, therefore, the profits arising from the sale of the slag are greater.

"9. The fuel consumption is lower in the Talbot furnace than in the other furnaces.

"10. The life of the refractory lining is longer in the Talbot furnace than in other systems, and thus both the charges for repairs and the total consumption of refractory material are lowest in the case of the Talbot furnace.

"11. The working of the furnace is, in the case of the Talbot furnace, most simple and convenient, especially on account of the easy removal of the slag by tipping the furnace.

"12. The work of the furnace staff is less trying with the Talbot furnace than with the other types; and the number of hands necessary for carrying out the process is, relatively, the smallest."

Selection of Process.—In comparing the advantages and disadvantages of different methods of manufacture, the most important points for consideration in the selection of a particular process are the local conditions, first as to the supply of the raw materials, and, secondly, the material it is desired to make, whether rail steel, dead soft steel, or steels of different percentages of Carbon to meet the requirements of various specifications. Thus in some parts of England and on the Continent the only pig-iron which can be manufactured locally is a Phosphoric one, and the cost of production is such compared to the cost of imported hematite pig-iron that any process depending upon the latter would be most seriously handicapped, and this would practically settle the question as to some basic process, capable of dephosphorising, being adopted. The percentage of Phosphorus in the pig-iron, whether 2·2 per cent. or more, would largely decide the question whether the process should be the Bessemer or the open hearth. Given a cheap pig of over 2·2 per cent. of Phosphorus, especially if there was a demand for rails, the basic Bessemer would probably better meet the conditions, but with less Phosphorus than this the basic open hearth process in some form would have to be adopted.

With regard to the basic Bessemer, one great difficulty connected with the process is to obtain iron ores containing sufficient Phosphorus to make a pig-iron with a minimum of 2·2 per cent. of Phosphorus, as although Phosphoric ores are very widely distributed, they rarely contain sufficient Phosphoric acid to produce a pig-iron with this quantity of Phosphorus, and consequently we are not likely to see any new basic Bessemer plants started.

On the other hand, assuming hematite pig-iron of good quality can be obtained at a price within a few shillings per ton of the price of basic pig-iron, the acid open hearth would certainly be selected, especially if it is desired to make all classes of Carbon steels. The advantages of the acid open hearth over the Bessemer are such that the latter would never be adopted except in some special cases where it is desired to make one particular class of finished product, such as rail steel, and even then it is doubtful if it would be advisable to lay out a new works for this process.

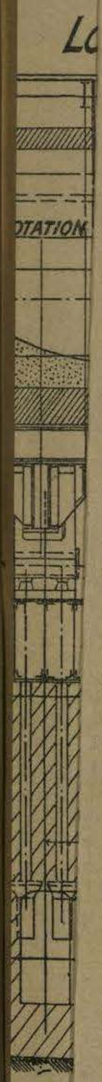
The scarcity of high-class iron ores capable of producing a pig-iron with less than 0·06 per cent. of Phosphorus suitable for acid Bessemer work is becoming greater and greater, and acid steel rail makers are finding it more and more difficult to obtain pig-iron at a price which they can afford to pay. For high-class steels for special purposes the acid Siemens will continue to be used, as in such cases specially selected pig-irons low in Phosphorus can be worked, the cost of the pig-iron not being such a serious question, as the price obtained for the finished product is so much higher.

It seems probable that in the future the basic open hearth, or some modification of it, will gradually supersede both the basic and acid Bessemer, and to some extent the acid open hearth, both for structural and rail steel, as there are large deposits of ores which are just too Phosphoric for acid work, and which would make an ideal pig-iron for basic open hearth practice. From many of these ores a pig-iron with about ·15 to ·5 per cent. of Phosphorus would be produced, and such a pig-iron worked under basic open hearth conditions would undoubtedly produce a far better material than is on the average produced either by the acid or basic Bessemer, as with such content of Phosphorus in the pig-iron the risk of making steel high in Phosphorus would be practically *nil*, or at all events not so great as the risks incurred by using hematite iron containing a percentage of Phosphorus dangerously near the limit allowed in acid open hearth practice.

The general use of liquid mixer metal for the basic open hearth process, and especially the considerable preliminary refining which is now effected in the mixer, has so increased the output and yield, that the cost of production has been considerably reduced, and to-day the basic open hearth processes are in a much stronger position than a few years ago, and everything points to the continued expansion of steel manufacture in this direction.

The following tables, taken from a very exhaustive paper by O. Petersen,* illustrate the reactions occurring under different conditions of basic open hearth practice, and in the Bertrand-Thiel and Talbot processes :—

* *Stahl und Eisen*, January, 1910, Nos. 9 and 10; *Iron and Coal Trades' Review*, January 21, 1910, *et seq.*



Longitudinal Section and Elevation of 200-ton Talbot Furnace erected at Witkowitz, showing fixed interchangeable port-blocks on the Fredrich system.

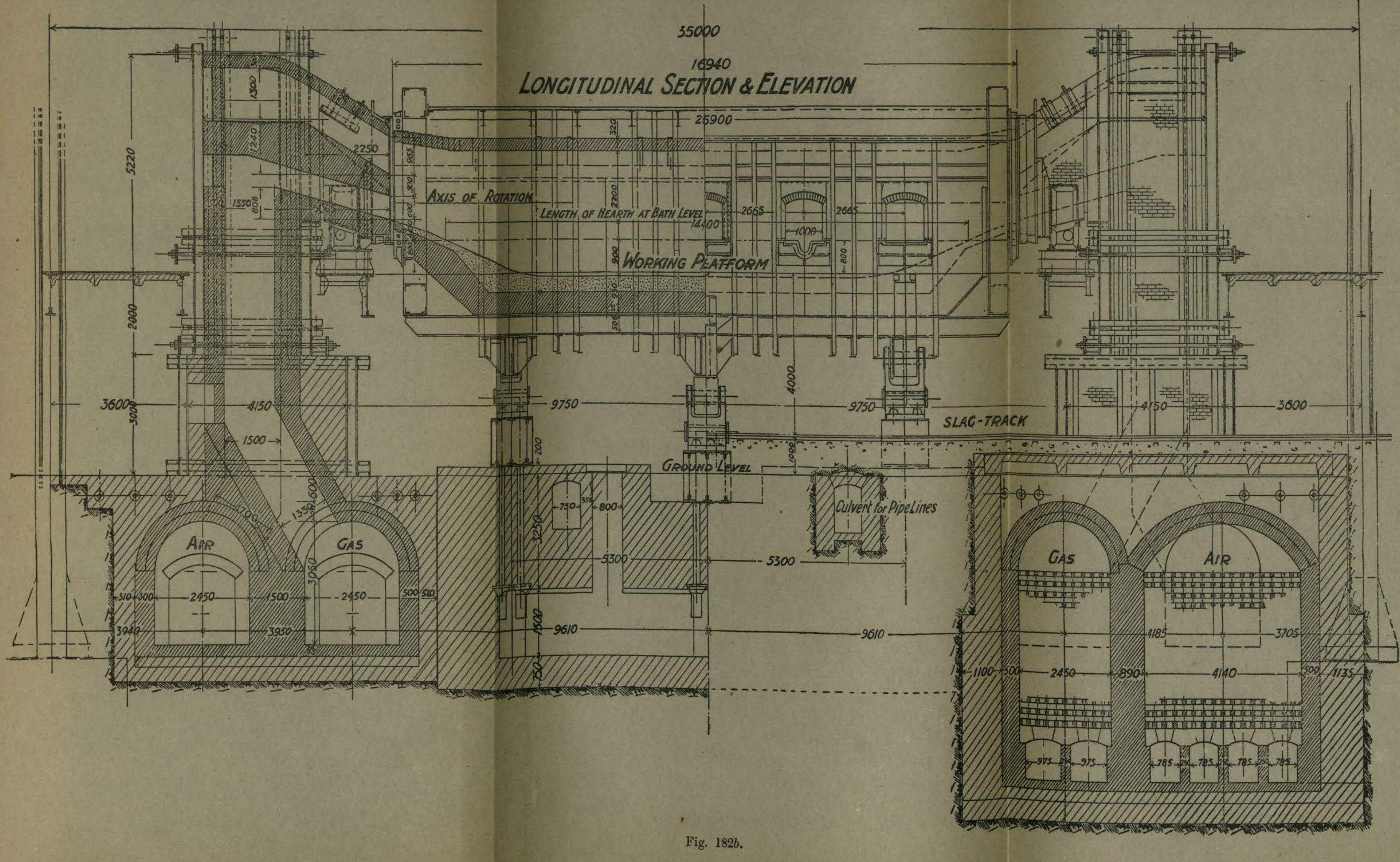


Fig. 182b.

Cross-section of the Talbot 200-ton Furnace erected at Witkowitz.

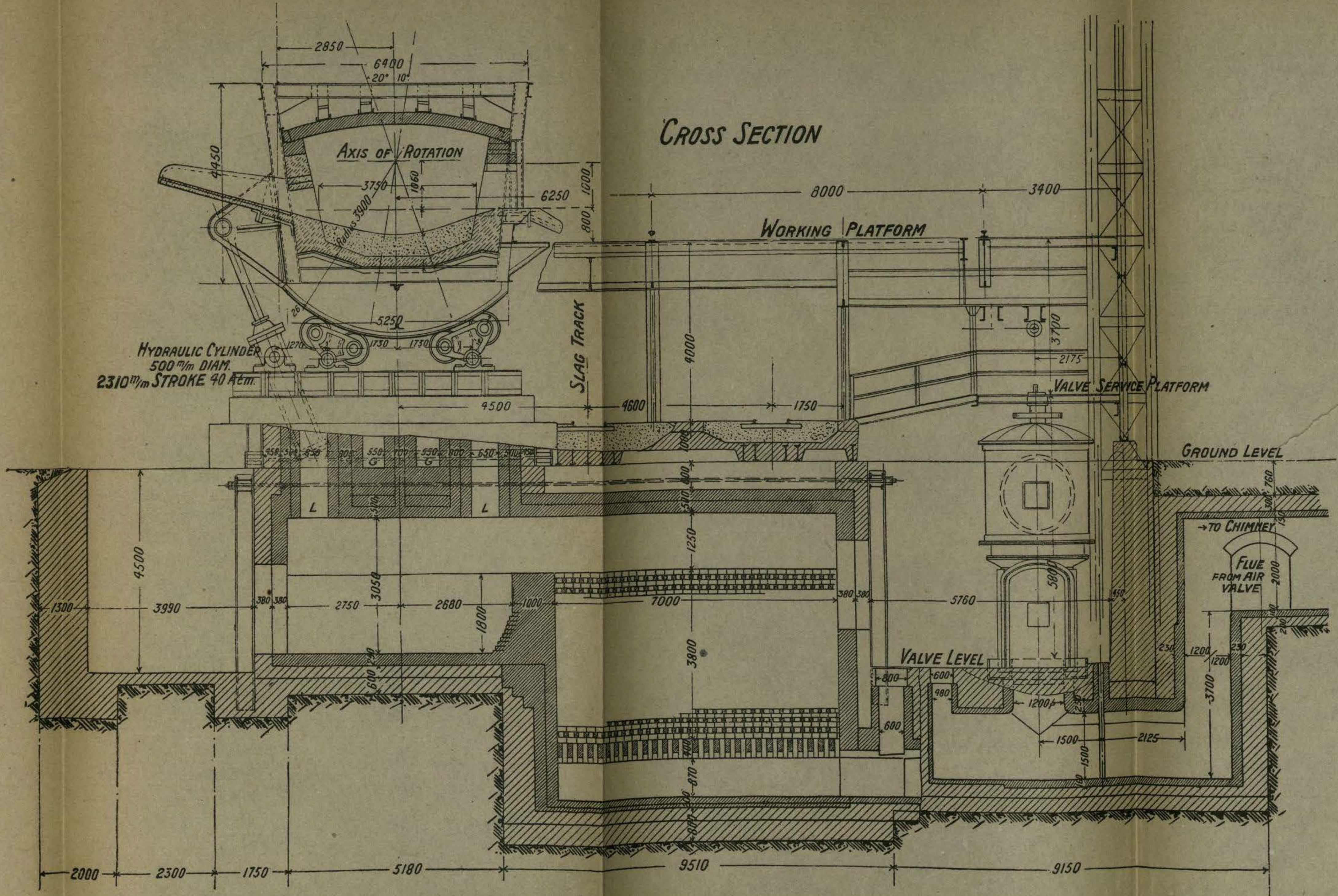


Fig. 182c.

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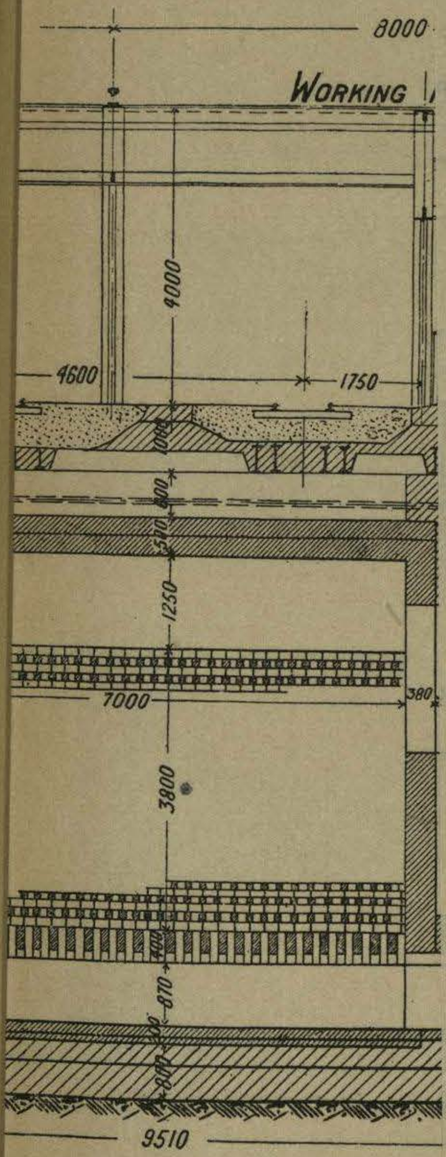

Fig. 182c.

Tables illustrating Reactions and showing Yields, &c., in Basic Open Hearth and similar Processes.

TABLE XXXVI.—Chemical Changes during the Hoesch Process.

	Sample taken at	Period.	Analysis of the Metal, per cent.					Analysis of the Slag, per cent.									Charge and Adjuncts.	Remarks.
			C.	P.	Mn.	Si.	S.	FeO.	MnO.	Al_2O_3.	CaO.	MgO.	P_2O_5.	S.	SiO_2.			
Charge No. 1,465	12.1	1st period.	3·28	1·86	0·96	0·32	0·132	...	...	...	...	...	...	...	...		Charge: 23,280 kg. pig; 1,880 kg. lime; 3,440 kg. Swedish ore; 770 kg. rolling mill scale.	Pig run in.
	1.1		2·47	0·590	0·17	Trace	0·102	...	...	...	...	...	...	...	...			
	1.3		1·90	0·470	0·22	...	0·098	10·25	5·03	1·36	41·56	4·32	22·85	0·069	12·20			
	1.4		1·65	0·370	0·22	...	0·098	7·06	4·96	1·38	45·48	4·00	22·36	0·124	11·80			
	2.30		1·46	0·260	0·34	...	0·082	4·67	3·93	1·60	48·86	4·00	22·13	0·138	11·40			
	2.0		...	...	...	...	...	...	...	...	...	...	...	...	...		Charge: 2,182 kg. Spathic ore; 5,412 kg. scrap; 1,290 kg. lime.	End of 1st period. Metal returned to furnace.
	3.50	Finishing period.	0·385	0·090	0·29	...	0·100	19·64	13·49	3·17	33·64	6·92	6·25	0·110	14·20		Adjuncts:	
	4.10		0·205	0·050	0·23	...	0·089	15·78	12·08	3·00	35·78	6·70	6·70	0·165	15·40		105 kg. rolling mill scale.	
	4.30		0·090	0·045	0·26	...	0·090	15·83	8·88	2·32	43·88	6·00	5·50	0·259	13·20			
	4.45		0·075	0·035	0·26	...	0·080	14·13	10·19	2·21	43·79	6·10	5·57	0·206	14·20		160 kg. lime; (4·55) 206 kg. lime.	
	5.5		0·058	0·035	0·27	...	0·078	16·23	8·32	2·20	45·30	5·90	5·55	0·275	14·00			
	5.10		0·045	0·030	0·25	...	0·077	17·20	7·67	2·00	46·19	6·12	5·15	0·316	13·10			
	5.15		0·080	0·040	0·47	...	0·067	17·03	10·25	1·90	46·28	5·92	5·00	0·344	12·40		200 kg. Ferro-Manganese.	Tapped.

The above tables show reactions, &c., in the Hoesch process, which is worked in two stages, the metal being largely dephosphorised during the first period, then tapped into a ladle to separate the slag, and returned to same furnace for final removal of Phosphorus and conversion into finished steel. The furnaces used are from 30 ton capacity, and average output is 60 tons per twelve hours.

Metallurgically, this method of working is identical with the Bertrand-Thiel process. During the first period the metal is largely dephosphorised, as much Carbon being retained as possible, and, instead of being transferred to a finishing furnace, it is tapped into a ladle and returned to the same furnace without the phosphoric slag, a new slag is made and the heat finished in the usual way.

TABLE XXXVII.—PRODUCTION AND CONSUMPTION (HOESCH PROCESS).

Charge (exclusive of Ore).								Output.		Iron per Ton of Sound Ingots.	Furnace Shifts.	Charges	Charges per Furnace Shift.	Sound Ingots.		Hard Steel Charge.
Basic Iron.	Hematite.	Spiegeleisen.	Ferro-Manganese.	Ferro-Silicon.	Scrap Iron.	Steel Scrap, &c.	Charge.	Sound Ingots.	Yield per cent. of Charge.					Per Day.	Per Charge.	
Kg. 36,209 647	Kg. 4,600	Kg. 120,950	Kg. 404,848	Kg. 7,080	Kg. 83,800	Kg. 11,631,695	Kg. 48,462,620	Kg. 50,605,965	104·42	Kg. 957·67	845·5	1,711	2·02	Kg. 119,474	Kg. 29,570	23
36,2 4,247 kg. 74·72 per cent.		Per cent. 0·25	Per cent. 0·84	Pr.cent. 0 02	Per cent. 0·17	Per cent. 24·00										
Of Charge.																

Consumption of	Kg.	Per 1,000 Kg. Sound Ingot.
Ore and rolling mill scale,	11,010,565	217·5
Coke, ...	177,060	3 0
White lime, . . .	4,749,275	94 0
Producer coal, . .	12,550,672	248·0
Basic material, . .	1,951,920	39·0
Boiler brick, . . .	161,858	3·0
Firebrick, . . .	422,506	8·0
Dinas brick, . . .	942,321	19·0
Welding-furnace brick, .	229,977	4·0
Flue brick, . . .	270,882	5 0
Magnesite brick, . .	46,089	1·0
Chamber brick, . .	126,877	2·0
Ladle lining, . . .	402,827	7·0
Fine sand, . . .	277,444	5·0

Slag produced in 1st Period, and ground to Phosphate Meal.

6,376 *t* with 20 to 25 per cent. P_2O_5 = 126 kg. per ton of ingots.

Slag from 2nd Period, used in Blast Furnaces.

7,439 *t* = 147 kg. per ton of ingots.

Analysis.— Molten Basic Iron from Mixer—
3·20 per cent. **C**; 1·82 per cent. **P**; 1·05 per cent. **Mn**; 0·41 per cent. **Si**; 0 084 per cent. **S.**

Metal at End of 1st Period—
1·95 per cent. **C**; 0·15 per cent. **P**; 0·36 per cent. **Mn**; traces **Si**; 0·07 per cent. **S.**

Slag from 1st Period—

	Per cent.		Per cent.		Per cent.		Per cent.
Fe	4·63	CaO	41·91	SiO_2	11·00	MgO	7·20
Mn	4·76	P_2O_5	24·93	Al_2O_3	2·10	S	0·36

Slag from 2nd Period—

	Per cent.		Per cent.		Per cent.		Per cent.
Fe	14·10	CaO	40·13	SiO_2	13·20	MgO	7·50
Mn	8·54	P_2O_5	7·47	Al_2O_3	2·99	S	0·44

Mild Steel—
0·07 per cent. **C**; 0·02 per cent. **P**; 0·44 per cent. **Mn**; 0·055 per cent. **S.**

Composition of Ore used—

	Rolling Mill Scale. Per cent.	Spathic Ore. Per cent.	Swedish Ore. Per cent.	Minette. Per cent.
Fe . .	72·34	47·18	63·7	34·98
Mn . .	0·57	8·21	0·2	0·28
P . .	0·02	0·06	1·5	0·70

TABLE XXXVIII.—CHEMICAL CHANGES IN CHARGE 4,850 (HUBERTUSHÜTTE).

Sample taken at o'clock.	Analysis of Metal, per cent.					Analysis of Slag, per cent.					Charges and Adjuncts.	Remarks.
	C.	Mn.	P.	Si.	S.	SiO_2.	CaO.	FeO.	MnO.	P_2O_5.		
12.45	...	...	...	...	...	...	...	...	...	...	22,400 kg. pig (3·61 per cent. **C**, 2·32 per cent **Mn**, 1·89 per cent. **Si**, 0·044 per cent. **S**, 0·67 per cent. **P**). 4,700 kg. Swedish magnetic ironstone. 900 kg. South Russian ore.	Furnace charged.
1.45	2·72	0·038	0·050	0·500	0·030	20·99	...	33·25	10·86	7·33	Adjuncts: Lime, 3 to 4 per cent. (1.45 to 4.45)	Bath hot and boiling.
2.15	2·45	0·046	0 035	0·050	0 030	20 98	...	33·70	11·00	7·30		,, ,, frothing commences.
2.45	2·34	0·046	0·027	0·031	0·028	21·15	...	30·14	11·29	6·96		Bath hot and frothing.
3.15	1·94	0·054	0·020	0·042	0·026	22·35	...	24·47	11·68	7·59		Bath frothing, but cooler.
3.45	1·76	0·061	0·040	0·065	0·026	23·66	...	19·02	11·91	7·81		,, ,, cold.
4.15	1·68	0·084	0·044	0·033	0·030	23·83	...	15·57	12·24	7·95		,, ,, ,,
4.45	1·17	0·154	0·065	0·053	0·026	24·55	...	11·12	12·19	7·40		Bath cold; frothing subsides.
5 0	1·14	0·199	0·094	0·035	0·034	25·76	...	9·57	11·80	7·21	. . . . . .	Bath grows hotter and boils.
5.15	0·82	0·261	0·140	0·017	0·028	...	Not tested.		...	...	. . . . . .	,, ,, ,,
5.45	0·71	0·307	0·138	0·015	0·028	22·67	...	7·44	10·43	6·41	400 kg. South Russian ore. .	Bath is hot and boils.
6.0	0·61	0·192	0·051	0·031	0·040	21·32	...	11·46	9·67	5·43	. . . . . .	,, ,,
6.20	0·375	0·253	0·019	0·015	0·036	22·56	...	9·90	9·28	6·89	400 kg. South Russian ore. .	,, ,,
7.0	0·090	0·261	0·059	0·010	0·030	21·87	...	10·57	8·38	6·30	. . . . . .	Sample is sufficiently mild.
7.15	0·084	0·269	0·035	0·020	0·038	21·17	...	10·34	7·95	6·21	160 kg. Ferro-Manganese. .	
7.30	0·087	0·499	0·067	0·004	0·042	20·29	...	9·45	9·24	5·73	. . . . . .	Furnace tapped.

Table xxxviii. shows the chemical changes during the working of very silicious molten blast-furnace metal charges at Hubertushütte. The furnaces are of 20- and 25-ton capacity. It will be noticed that the slag is very silicious, and consequently the Phosphoric Acid is not strongly held, and is frequently reduced and passes back into the metal during the working of the charge. The time of working such charge is $6\frac{3}{4}$ hours, and the average, with charge containing 1 per cent. or less of Silicon, $5\frac{1}{2}$ hours.