ON THE MANUFACTURE OF HÆMATITE IRON.

 BY MR. WILLIAM CROSSLEY, OF ASKAM-IN-FURNESS.

In the Hæmatite district of Lancashire and Cumberland, owing to the peculiarities of the materials employed and other causes, it has not been practicable to make use of all the most recent improvements in the working of blast furnaces, or to keep pace with the rapid progress effected elsewhere; but it is thought a description of the results obtained may not be altogether out of place in a district like Cleveland, where the manufacture of iron is carried on in the most scientific manner and with the most approved appliances.

The Blast Furnaces of the hæmatite district are much the same as those at work in Cleveland, but the appliances for working them are not usually quite so good. Those at work at Barrow may be taken as a fair type of most hæmatite furnaces as to size and capacity; they are about 55 feet high and 16 feet diameter at the boshes, having a capacity of about 9,000 to 10,000 cubic feet. The furnaces at the Furness Iron and Steel Works, Askam, with which the writer is connected, are 67 feet high and 19 feet diameter at the boshes, tapering to 18 feet below the gas outlet, as shown in Figs. 1 and 2, Plate 37; and they have a capacity of 13,100 cubic feet, which the writer understands is greater than that of any other hæmatite furnaces at present working. The various attempts which have been made to work larger furnaces for hæmatite ores do not seem to have been attended with such success as to justify the erection of others; and in one or two instances where furnaces of 75 feet height have been erected, the results obtained have been so unsatisfactory that the furnaces have been blown out and the height diminished to 55 or 60 feet. The Askam furnaces of 67 feet height did not work well for some time when they were first blown in; the cause of their bad working was attributed to the smallness

of the charging bells in proportion to the width of the furnaces, and consequently larger bells were substituted. The bells at first employed were only 7 ft. 6 ins. diameter; but the present ones are 12 ft. 6 ins. diameter, as shown in Fig. 5, Plate 39, and these are believed to be the largest of any yet used for hæmatite furnaces. These furnaces now work with great regularity, and each produces weekly from 400 to 460 tons of iron, a large proportion being of a quality suitable for Bessemer converters.

The general form of these furnaces is shown in Figs. 1 and 2, Plate 37, and the principal dimensions are as follows:—

Height	67 feet.
Diameter at boshes	19 „
„ throat	18 „
„ hearth	7 „
Heating surface	5500 square feet.
Number of tuyeres	6
Area of blast inlet	75 square inches.
Pressure of blast at engine	3 lbs.
„ „ tuyeres	2 $\frac{3}{4}$ lbs.
Area of gas outlet	18 square feet.
Diameter of charging bell	12 ft. 6 ins.
Weekly make of iron per furnace	400 to 460 tons.

For taking off the blast-furnace gas, the bell and hopper arrangement adopted in the Cleveland district has not been found to answer so well in the hæmatite furnaces; and the writer is informed that the Carnforth and Askam Works are the only two places at which this plan is at work in the hæmatite district. In Fig. 5, Plate 39, is shown the closed top of the Askam furnaces, with the outlet opening for taking off the waste gas. The reasons advanced for not adopting the closed-top plan at other places are—first, that it is believed to act prejudicially upon the quality of the iron produced; and secondly, that it throws a heavier back pressure on the furnaces, and thus interferes with their regular working. The first objection the writer thinks cannot be entertained without some more positive proof than has at present been advanced; and the second is met by the fact that there are hæmatite furnaces in which the closed top has been adopted with apparently perfect success, and it has not been found that increased back pressure acts prejudicially in any way,

excepting so far as it throws increased work on the blowing engines. This latter point the writer has not tested by throwing any particularly heavy back pressure on the furnaces; but he draws the conclusion from the circumstance that a furnace in which two gas outlets were provided, one of 4 ft. and the other of 5 ft. diameter, was not found to work in any way better than another furnace with only one 5 ft. outlet, all other conditions being the same. Moreover in working a furnace for eight or ten months continuously, the flues and gas outlet get gradually contracted in area, and throw a greater back pressure on the furnace, without however interfering in any way with the regularity of its working. If this experience is confirmed by the results obtained elsewhere, it is evident that some other explanation must be sought of the alleged failure of the closed-top system; and in the writer's opinion the sole explanation is to be found in an improper distribution of materials, owing to the bell not being suitably proportioned to the size of the furnace throat. In respect to this point it is better to err in having the bell rather too large, than incur any risk of its being too small.

The furnace shown in Figs. 3 and 4, Plate 38, is one at present building at Askam, which is expected to be ready for blast in a couple of months. It is 75 ft. high, 23 ft. diameter at the boshes, and has a bell 14 ft. diameter. The object in adopting these dimensions has been to ascertain whether the same advantages will result from increasing the height up to 75 feet which have been obtained in Cleveland; and the diameter of 23 feet, which is greater than that of any furnace previously built in the hæmatite district, has been decided upon under the conviction that, owing to the compact nature of the materials, it is necessary the diameter should be increased, in order to maintain regularity in the descent of the materials, and also to facilitate the upward passage of the blast, which has constituted one of the difficulties met with in high and narrow hæmatite furnaces.

The arrangement of furnace top shown in Fig. 6, Plate 39, or some modification of it, is usually adopted where the gas from open-topped hæmatite furnaces is utilised, the gas being taken off through a series of openings round the furnace throat, which is contracted

in diameter more abruptly at that part. This construction is found to answer the purpose of distributing the materials very fairly, and at the same time of taking off a large proportion of the gas to the stoves and boilers; but in the writer's opinion it can only be looked upon as a compromise, and not as a plan to be satisfied with. In Figs. 7 and 8, Plate 40, is shown the semi-closed top used at the Barrow furnaces, in which the gas is taken off through a central gas tube as well as through openings round the furnace throat.

Of the materials used in the production of hæmatite iron the principal is the hæmatite ore, found in large quantities in North Lancashire and Cumberland, and generally known as the ore of the Furness and Whitehaven districts. This ore occurs principally in two varieties, one of which is hard, compact, and almost free from moisture, while the other variety is soft and wet. The hard ore is almost invariably used in the production of hæmatite pig iron, and is therefore called blast ore; while the softer quality is used for fettling puddling furnaces, and is called puddling ore. The blast ore of Whitehaven and Furness does not differ much in quality, both districts yielding good and bad varieties; but there can be no doubt that the best Whitehaven ores are richer in iron than the best Furness ores. In Furness the poorer blast ores usually contain about 45 per cent. of metallic iron, while the better qualities run up to 57 and in some cases 60 per cent.; in Whitehaven the poorer ores contain about 50 per cent. of metallic iron, and the best run up to 60 or 65 per cent.; but the average percentage of iron in the ores used in both districts is probably between 57 and 60 per cent.

The ore used at Askam has the following composition:—

TABLE I.

Analysis of Askam Ore.

	Per cent.
Peroxide of Iron	83·00
Silica	15·50
Carbonate of Lime	trace
Moisture	1·50
	<hr/> 100·00 <hr/>
<i>Percentage of Metallic Iron</i>	<i>58·10</i>

It will be observed that the principle impurity is silica; and unlike the Cleveland and most other ores, this ore does not contain any alumina. It is therefore thought desirable at many places to mix it with aluminous ores, for the purpose of producing a better slag, and also in order to obtain greater regularity in the working of the furnace. The addition of these aluminous ores also gives the means of controlling in some measure the percentage of silica in the iron.

The aluminous ores are mostly obtained from Ireland, and are so readily accessible that they can be had at a reasonable cost. Three principal varieties of Irish ores are used in the manufacture of hæmatite iron, and these are fairly represented by the three ores known as lithomarge, red aluminous iron ore, and black nodular iron ore. The accompanying Table shows their respective composition:—

TABLE II.
Analysis of Aluminous Iron Ores.

	Lithomarge.	Red Aluminous Ore from Larne.	Black Nodular Ore from Red Bay.
	Per cent.	Per cent.	Per cent.
Silica	30·70	11·25	6·00
Alumina	27·05	35·61	20·37
Titanic acid	trace	trace	0·75
Peroxide of Iron	25·05	34·65	71·63
Protoxide of Iron	trace	none	0·68
Magnesia and Lime	1·11	trace	trace
Water of combination	15·85	16·30	1·15
	99·76	97·81	100·58
<i>Percentage of Metallic Iron .</i>	17·53	24·25	50·67

From this it will be seen that the proportion of alumina to silica in the lithomarge is about in equal quantities, being 27 and 30 per cent., while in the aluminous ore from Larne, and the black nodular from Red Bay it is about 3 to 1; and as the red variety contains about 35 per cent. of alumina against 20 per cent. in the black nodular, it is evident that under ordinary circumstances the red variety would be

preferred; but at present the price of hæmatite ore is so much in excess of that of the Irish ores, that it becomes a matter for consideration whether it is not worth while to use the black nodular for the sake of the iron alone, a larger quantity of this ore being then required to produce a slag containing the proper proportion of alumina.

The lithomarge has been longest in use, and is preferred at some works; but the writer believes the other two varieties to be better for most purposes, because the percentage of silica in the lithomarge is so high in proportion to the alumina that a very large quantity of the ore must be used to produce any appreciable difference in the composition of the slag and in the smelting of the materials in the furnace. A still more serious objection to the lithomarge is the high percentage of moisture it contains, which must have a very injurious effect in cooling the escaping gases of the furnace, and thus increasing the consumption of fuel per ton of iron. This will be more fully seen by the following calculation. Supposing that 4 cwts. of lithomarge be used per ton of pig iron, and that this contains 15 per cent. of moisture; then 0.6 cwt. of water per ton of iron would have to be liberated from combination, vaporised, and further raised to the temperature of the escaping gases; and supposing this latter temperature be 500° Fahr., the cwt.-units of heat escaping in the form of steam will be 907. Then assuming that each cwt. of coke burnt in a blast furnace gives out 4320 Fahr.-cwt.-units of heat, it follows that 0.21 cwt. or $\frac{1}{4}$ cwt. of coke per ton of iron produced will be required to drive away the moisture from the lithomarge alone. This however is not all; for in addition to containing water of combination, lithomarge has a great attraction for moisture, and generally contains from 5 to 10 per cent. of hygroscopic water, which has also to be vaporised and raised to the temperature of the escaping gases; and if to this be added the coke requisite for melting 4 cwts. of material which can scarcely be called iron-producing, the total loss of fuel amounts to at least $\frac{3}{4}$ cwt. of coke per ton of iron made; and this means a reduced make, and therefore an increased cost not fully represented by the increased consumption of coke alone.

It will be seen that the red aluminous ore has also the disadvantage of containing usually about 15 or 16 per cent. of moisture; this not only occasions a waste of fuel, as in the case of the lithomarge, but the red ore having also a tendency to fall to powder, the contained moisture causes it then to assume a pasty condition, which leads to bad distribution of the materials in the furnace, and the ore is thus mechanically objectionable. The black nodular ore from Red Bay is free from the objection of containing combined water, and owing to the compact character of the nodules it does not so readily absorb moisture as either lithomarge or red aluminous ore; and as it contains a high percentage of iron, amounting to as much as 50 per cent. of metallic iron, with a large excess of alumina over silica, the proportions of the two being 20 and 6 per cent. respectively, it affords the means of neutralising the effect of the silica in the hæmatite ore, without increasing the consumption of fuel per ton of iron made, or diminishing the make of the furnace.

The hæmatite ore being found in a limestone formation and worked in the district, there is a plentiful supply of good and cheap limestone. That used at Askam is obtained from a neighbouring quarry at Stainton, and has the following composition:—

TABLE III.

Analysis of Stainton Limestone.

	Per cent.
Carbonate of Lime	95·00
Carbonate of Magnesia	4·20
Silica	0·50
Oxide of Iron, and Alumina	0·30
	<hr/>
	100·00
	<hr/>

The coke used is almost entirely obtained from the Durham coalfield, and is usually of the very best quality. The average composition of the coke used at Askam is as follows:—

TABLE IV.
Analysis of Durham Coke.

	Per cent.
Sulphur	0·70
Ash	5·00
Moisture and loss	0·92
Carbon (by difference)	93·38
	<hr/>
	100·00
	<hr/>

In working a material so difficult to deal with as the hæmatite ore, the first and most important point to be attended to is the proper distribution of the materials in the furnace. In the open-topped and semi-closed furnaces this is easily done by keeping the furnace always full to the same height, and putting in small charges in regular rotation. In the case of close-topped furnaces the same object is accomplished, either by taking care to have the charging bell properly proportioned to the diameter of the furnace, as previously mentioned; or else by gauging at frequent intervals with an iron rod, in order to make sure that the materials shall never be above or below the height which has been proved by experience to give the most satisfactory results. The gauging must be done not only at one but at various points round the circumference of the furnace, as it is found that there is a tendency at times to drive unequally on different sides; and this may be counteracted by regulating the supply of blast by means of a valve fixed to each tuyere. It is also necessary to prevent the ore being charged in too large pieces; otherwise it is found excessively difficult, owing to the compact nature of the ore, to ensure its perfect reduction before it reaches the part of the furnace at which it is melted.

A further difficulty is met with in keeping the tuyere-breasts good, as any fretting at these places leads to the necessity for changing the tuyeres, and consequently occasions irregularity of working in the furnace. To obviate this as much as possible, the construction of tuyere and tuyere-breast shown in Figs. 9 and 10, Plate 41, has been adopted, consisting of a close double coil of water pipe; the large outer coil A A is 14 inches diameter and of the depth

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of the tuyere-breast, and in the centre of it the tuyere B is packed with clay C C; in the event of the tuyere leaking, it can then be easily removed by taking out the clay, and another tuyere can be substituted, the whole process of changing the tuyere occupying only from 10 to 15 minutes. This plan was first adopted at the Ormesby Iron Works, Middlesbrough, to protect the tuyere-breasts, which were found to work hot; and it has also been found to facilitate very much the process of changing the tuyere. As nothing interferes so much with the regularity of working of a blast furnace as trouble with the tuyere-breasts and changing the tuyeres, this simple plan has proved to be of considerable value in removing those sources of difficulty.

The result of the working of the Askam No. 2 furnace, of 67 ft. height, 19 ft. diameter, and 13,100 cubic feet capacity, has been found to be a consumption of $22\frac{3}{4}$ cwts. of coke per ton of iron made, when working on Bessemer iron and using the Askam ore mixed with about 10 per cent. of black nodular ironstone, known as Fisher's Red Bay Ore, and fluxed with $9\frac{1}{4}$ cwts. of limestone per ton of iron made. The average temperature of the blast during a considerable period of observation was 934° Fahr., and that of the escaping gases at the furnace top about 712° Fahr.

The composition of the escaping gases has been found by analysis after drying them to be as follows, at a time when their temperature was 732° Fahr., and that of the blast 968° :—

TABLE V.

Analysis of Escaping Gases from Askam Blast Furnace.

	By Volume.	By Weight.
	Per cent.	Per cent.
Nitrogen	54.51	52.59
Carbonic oxide	34.97	33.80
Carbonic acid	8.36	13.47
Hydrogen	2.16	0.14
	100.00	100.00

The weight of the escaping gases is 120 cwts. per ton of iron made, and the quantity of heat carried off by them when escaping at the temperature of 732° Fahr. amounts consequently to 22,669 Fahr.-cwt.-units, one such unit being the quantity of heat required to raise 1 cwt. of water through 1 degree of temperature Fahr. The weight of blast supplied to the furnace is $82\frac{1}{2}$ cwts. per ton of iron made, which at the temperature of 968° Fahr. introduces into the furnace 19,176 units of heat; this is in the proportion of about 85 per cent. of the heat that is carried off by the escaping gases.

The details of the production and absorption of heat in the furnace are appended to the present paper; and for the purpose of comparison with the results of the working of the Cleveland furnaces, they are given in a tabulated form similar to that employed by Mr. I. Lowthian Bell for the Cleveland furnaces. The total quantity of heat produced in the Askam furnace by the combustion of the coke and by the blast amounts to 150,000 cwt.-units per ton of iron made, of which 40 per cent. is absorbed in the actual reduction of the iron from the ore, and 15 per cent. is carried off in the escaping gases, the remainder being accounted for by the other operations taking place within the furnace.

The composition of the Bessemer and forge iron made in the furnace, and also of the slag, is given in the following Tables:—

TABLE VI.

Analysis of Askam Hæmatite Pig Iron.

	No. 1 Bessemer Iron.	No. 3 Bessemer Iron.	No. 4 Forge Iron.
	Per cent.	Per cent.	Per cent.
Carbon, uncombined .	3·928	3·377	2·719
„ combined .	0·109	0·469	1·222
Silicon . . .	2·640	2·424	1·608
Aluminium . . .	trace	trace	trace
Manganese . . .	0·093	0·021	0·021
Calcium . . .	0·021	0·050	0·074
Magnesium . . .	trace	trace	trace
Sulphur . . .	0·004	0·004	0·031
Phosphorus . . .	0·014	0·010	0·016
Iron . . .	93·191	93·645	94·309
	100·000	100·000	100·000

TABLE VII.

Analysis of Slag from Askam Blast Furnace.

	Per cent.
Silica	38.00
Alumina	10.00
Lime	42.19
Magnesia	1.65
Sulphuret of Calcium	2.45
Protoxide of Iron	2.08
Potash	1.60
Protoxide of Manganese	trace
Soda and loss	2.03
	<hr/> 100.00 <hr/>

The quantity of coke used— $22\frac{3}{4}$ cwts. per ton of iron made—may seem large as compared with the consumption in the Cleveland furnaces, in which, although a much poorer variety of stone is employed, the consumption of coke is not more than from 20 to $21\frac{1}{2}$ cwts. per ton of iron; but it is to be remembered that the $22\frac{3}{4}$ cwts. is the result obtained in making Bessemer iron, which requires a specially high intensity of heat. The same furnace making forge iron would work well with about 2 cwts. less coke per ton of iron; and the temperature of the escaping gases has been found to be much lower when this quality of iron is being intentionally produced.

Another point worthy of attention is the small percentage of carbonic acid in the escaping gas, amounting to only 13 per cent. This seems to indicate, either that the ore is not so easily reducible as has generally been supposed; or that, owing to its compact nature or else its bad mechanical condition, the reducing gases do not ascend with the regularity which is obtained in a Cleveland furnace, and therefore do not effect that amount of reduction in the higher and cooler part of the furnace which is favourable to the production of carbonic acid at such a temperature as to prevent its own subsequent reduction to carbonic oxide; and the very high temperature of the escaping gases from the hæmatite furnaces appears to the writer to support such a conclusion.

It is also evident from the examination of these results, that, if it be possible in the Cleveland district to get the gases evolved from the furnace at as low a temperature as 312° Fahr. (as in the very large furnaces of 105 feet height at Ferryhill), and containing as much as 15 per cent. of carbonic acid, then it follows that for the purpose of making Bessemer iron the maximum size of furnace for working with the greatest economy of fuel has not yet been reached in the hæmatite district. On the other hand it must also be remembered that the hæmatite ore is a material which is not so easily worked as Cleveland ironstone, and does not admit of that free passage of the ascending gases which is so essential to the good working of a furnace. In fact there are other questions of working to be considered in the manufacture of Bessemer iron, which are as important as economy in fuel, if not more so; and although the 75 feet furnace now building at Askam is not the first hæmatite furnace of that height which has been built, and previous steps taken in the direction of increased height have not answered the expectations raised respecting them, the writer believes there are sufficient grounds for feeling sanguine as to the success of the present attempt.

APPENDIX.

From the analysis given in Table V of the escaping gases from the Askam furnace, their ultimate composition is ascertained. The 33·80 per cent. of carbonic oxide ($\text{CO} = 6 + 8 = 14$) is equivalent to $\frac{6}{14} \times 33\cdot80 = 14\cdot49$ per cent. of carbon, with $\frac{8}{14} \times 33\cdot80 = 19\cdot31$ per cent. of oxygen; and the 13·47 per cent. of carbonic acid ($\text{CO}_2 = 6 + 16 = 22$) is equivalent to $\frac{6}{22} \times 13\cdot47 = 3\cdot67$ per cent. of carbon, with $\frac{16}{22} \times 13\cdot47 = 9\cdot80$ per cent. of oxygen. Hence the ultimate composition of the escaping gases by weight after being dried is as follows:—

TABLE VIII.
Ultimate Composition of Escaping Gases.

	Per cent.	Nitrogen.	Oxygen.	Carbon.	Hydrogen.
Nitrogen . . .	52.59	52.59	—	—	—
Carbonic oxide .	33.80	—	19.31	14.49	—
Carbonic acid . .	13.47	—	9.80	3.67	—
Hydrogen . . .	0.14	—	—	—	0.14
	100.00	52.59	29.11	18.16	0.14

The actual weight of the escaping gases per ton of iron made is arrived at by ascertaining the total quantity of carbon introduced into the furnace, and calculating from this the actual quantity passing off in the escaping gases. The consumption of coke per ton of iron made is found by actual measurement to be 22.75 cwts.; and deducting 6.62 per cent. of this = 1.50 cwt. for ash &c., in accordance with the analysis given in Table IV, the consumption of carbon is 21.25 cwts. The flux of 9.25 cwts. of limestone contains, as shown in Table III, 95.00 per cent. of carbonate of lime [$\text{CaO}, \text{CO}_2 = (20 + 8) + (6 + 16) = 50$], and 4.20 per cent. of carbonate of magnesia [$\text{MgO}, \text{CO}_2 = (12 + 8) + (6 + 16) = 42$]; and the weight of carbon contained in the limestone is therefore $\frac{6}{50} \times 95.00 + \frac{6}{42} \times 4.20 = 11.40 + 0.60 = 12.00$ per cent. of 9.25 cwts. = 1.11 cwt. of carbon. The total weight of carbon supplied into the blast furnace per ton of iron made is accordingly $21.25 + 1.11 = 22.36$ cwts. of carbon; and the analysis of the pig iron given in Table VI shows that the 1 ton of pig iron made takes up 4 per cent. = 0.80 cwt. of carbon, leaving therefore 21.56 cwts. as the actual quantity of carbon passing off in the escaping gases.

Coke used per ton of iron . . .	22.75	
Less ash &c.	1.50	
Carbon contained in coke . . .	21.25 cwts.	Carbon available for heat production. <u>20.14 cwts.</u>
Do. do. limestone . . .	1.11 "	
Total Carbon in coke and limestone . .	22.36 "	
Less carbon taken up in pig iron . . .	0.80 "	
Carbon carried off in escaping gases . .	<u>21.56 cwts.</u>	

As the quantity of carbon carried off in the escaping gases has already been seen in Table VIII to form 18.16 per cent. of their weight when dried, it follows that the total weight of the escaping gases per ton of iron made is $100.00 \times \frac{21.56}{18.16} = 118.72$ cwts. when dried; and the weight of their several constituent elements is in the same way ascertained to be as given in the following Table IX. The ore charged into the furnace contains about 1.00 cwt. of water, and the coke 0.58 cwt., making together 1.58 cwt. of water, which is simply evaporated without being decomposed, and passes off as steam in the escaping gases; their total weight on leaving the furnace top is therefore 120.30 cwts. per ton of iron made.

TABLE IX.

Actual Weight and Composition of Escaping Gases per ton of iron made.

	Cwts.	Nitrogen.	Oxygen.	Carbon.	Hydrogen.
Nitrogen	62.44	62.44	—	—	—
Carbonic oxide . . .	40.13	—	22.93	17.20	—
Carbonic acid	15.99	—	11.63	4.36	—
Hydrogen	0.16	—	—	—	0.16
Steam (not decomposed)	1.58	—	—	—	—
Total weight of gases .	<u>120.30</u>	62.44	34.56	21.56	0.16

The weight of the blast supplied to the furnace can now be ascertained, as this will contribute the whole amount of the nitrogen contained in the escaping gases, 62.44 cwts., which will be accompanied by $\frac{23}{77} \times 62.44 = 18.65$ cwts. of oxygen, and also by $0.16 \times 9 = 1.44$ cwt. of moisture in the air, giving 82.53 cwts. as the total weight of blast supplied per ton of iron made.

Nitrogen	62.44 cwts.
Oxygen	18.65 „
Moisture	1.44 „
Weight of Blast per ton of iron made	<u>82.53 cwts.</u>

The heat contributed by the 82·53 cwts. of blast at the temperature of 968° Fahr. (520° C.) is as follows, taking the specific heat of air as 0·24, that of water being 1·00 :—

Heat contributed by blast = $82·53 \times 0·24 \times 968 = 19,176$ Fahr.-cwt.-units.

The heat carried off by the 120·30 cwts. of escaping gases at the temperature of 732° Fahr. (389° C.) is as follows, taking their specific heat to be the same as that of air 0·24, and adding the latent heat in the 1·58 cwt. of steam :—

Sensible Heat in gases = $120·30 \times 0·24 \times 732 = 21,133$ Fahr.-cwt.-units.

Latent Heat in steam = $1·58 \times 1·00 \times 972 = 1,536$ „

Total Heat carried off in escaping gases 22,669 „

In the following Tables X and XI is given an estimate of the *heat produced* and also of the *heat absorbed* per ton of iron made in the Askam No. 2 furnace, of 67 feet height, 19 feet diameter, and 13,100 cubic feet capacity, with the consumption of 22·75 cwts. of coke, and with a flux of 9·25 cwts. of limestone. In the estimate of the heat produced, the quantity of carbon available for the furnace work is rather less than the whole weight of carbon 21·25 cwts. supplied in the coke, because the carbonic acid in the limestone containing 1·11 cwt. of carbon requires another equal quantity of carbon for its reduction to carbonic oxide ($\text{CO}_2 + \text{C} = 2\text{CO}$), thus leaving only 20·14 cwts. as the quantity of carbon available for heat production. In the estimate of the heat absorbed, the latent heat of the steam in the escaping gases is taken into account as part of the furnace work, under the head of evaporation of the water contained in the ore and coke; consequently the item of the heat carried off in the escaping gases includes here only their sensible heat. As the ores used do not contain any sulphur, no item appears for expulsion of sulphur; the small percentage found in the pig iron, as shown in Table VI, is therefore obtained from the coke, in which it probably exists as sulphide of iron. Table X gives the estimate in Fahrenheit-cwt.-units, and the corresponding Centigrade-cwt.-units are given in Table XI.

TABLE X.

Production and Absorption of Heat per ton of iron made, in Fahrenheit-cwt.-units.

HEAT PRODUCED.			HEAT ABSORBED BY FURNACE WORK.			
	cwts.	Fahr. units.		cwts.	Fahr. units.	
Combustion of 20·14 cwts. of carbon into carbonic oxide	20·14 ×	4320 = 87,005	Evaporation of 1·00 cwt. of water from ore	1·00 ×	970 =	970
Further combustion of 4·36 cwts. of above carbon into carbonic acid	4·36 ×	10080 = 43,848	Evaporation of 0·58 cwt. of water from coke	0·58 ×	970 =	563
Heat introduced by Blast		19,176	Impregnation of pig iron with 0·80 cwt. of carbon from carbonic oxide	0·80 ×	4320 =	3,456
Total Heat Produced		150,029	Expulsion of carbonic acid from 9·25 cwts. of limestone	9·25 ×	670 =	6,197
			Reduction to carbonic oxide of the above carbonic acid containing 1·11 cwt. of carbon (10080 - 4320 = 5760 units)	1·11 ×	5760 =	6,394
			Reduction of 18·60 cwts. of iron from peroxide	18·60 ×	3200 =	59,520
			(93 per cent.* of 20 cwts. = 18·60 cwts.)			
			Decomposition of moisture in blast, contain- ing 0·16 cwt. of hydrogen	0·16 ×	61200 =	9,792
			Reduction of 0·52 cwt. of silicon from silica (2·6 per cent.* of 20 cwts. = 0·52 cwt.)	0·52 ×	14400 =	7,488
			Fusion of 20 cwts. of pig iron	20·00 ×	590 =	11,800
			Fusion of 15 cwts. of slag	15·00 ×	990 =	14,850
			Total Heat Absorbed by furnace work			121,030
			LOSS.			
			Transmission through walls of furnace			7,781
			Carried off in tuyere water			3,272
			Carried off in escaping gases			21,133
			Total Heat Escaping from furnace			32,186
						153,216
			(* See Table VI.)			
						153,216

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TABLE XI.

Production and Absorption of Heat per ton of iron made, in Centigrade-cwt.-units.

HEAT PRODUCED.			HEAT ABSORBED BY FURNACE WORK.		
	cwts.	Cent. units.		cwts.	Cent. units.
Combustion of 20.14 cwts. of carbon into carbonic oxide	20.14	$\times 2400 = 48,336$	Evaporation of 1.00 cwt. of water from ore	1.00	$\times 540 = 540$
Further combustion of 4.36 cwts. of above carbon into carbonic acid	4.36	$\times 5600 = 24,360$	Evaporation of 0.58 cwt. of water from coke	0.58	$\times 540 = 313$
Heat introduced by Blast		10,300	Impregnation of pig iron with 0.80 cwt. of carbon from carbonic acid	0.80	$\times 2400 = 1,920$
Total Heat Produced		82,996	Expulsion of carbonic acid from 9.25 cwts. of limestone	9.25	$\times 370 = 3,422$
			Reduction to carbonic oxide of the above carbonic acid containing 1.11 cwt. of carbon (5600 - 2400 = 3200 units)	1.11	$\times 3200 = 3,552$
			Reduction of 18.60 cwts. of iron from peroxide	18.60	$\times 1780 = 33,108$
			(93 per cent.* of 20 cwts. = 18.60 cwts.)		
			Decomposition of moisture in blast, contain- ing 0.16 cwt. of hydrogen	0.16	$\times 34000 = 5,440$
			Reduction of 0.52 cwt. of silicon from silica (2.6 per cent.* of 20 cwts. = 0.52 cwt.)	0.52	$\times 8000 = 4,160$
			Fusion of 20 cwts. of pig iron	20.00	$\times 330 = 6,600$
			Fusion of 15 cwts. of slag	15.00	$\times 550 = 8,250$
			Total Heat Absorbed by furnace work		67,305
			LOSS.		
			Transmission through walls of furnace		4,323
			Carried off in tuyere water		1,818
			Carried off in escaping gases		11,230
			Total Heat Escaping from furnace		17,371
					<u>84,676</u>
			(* See Table VI.)		
					<u>84,676</u>

Mr. C. COCHRANE remarked that for making forge iron the consumption named in the paper of $20\frac{3}{4}$ cwts. of coke per ton of iron appeared to him rather high, and with the Askam ore containing 58 per cent. of metallic iron he should have expected 17 or 18 cwts. of coke would be sufficient. The desirability of having blast furnaces so high as 75 feet was an important question now occupying attention in the hæmatite district, where no greater height than 55 feet had yet been generally adopted; the previous endeavours to work the higher furnaces he believed had generally proved unsatisfactory hitherto, and he understood that in one case a furnace of 75 feet height had subsequently been cut down to 61 feet: in that instance it was to be regretted that the charging bell had not been enlarged in diameter to the extent recommended in the paper. One great difficulty in the working of the hæmatite furnaces had been the liability to "scaffolding," and he understood the high furnace had been found liable to "hang" altogether for periods of ten or twelve hours at a time, during which it did not "drive" at all. The scaffolding was no doubt accounted for in a great measure by the small size and peculiar nature of the ores worked in the hæmatite furnaces, as explained in the paper, causing the ascending gases to carve out local passages for themselves in different directions, instead of ascending uniformly through all parts of the large area of the furnace; and he hoped to hear that with increased height of furnaces means were found for obviating these difficulties in the working.

Mr. W. CLAY enquired whether there was any difficulty in obtaining a sufficient quantity of gas from the Askam furnaces for heating the steam boilers. At the Millom Iron Works in the same district, with which he was connected, the quantity of gas obtained from four semi-closed furnaces was not sufficient for all the boilers and stoves, two or three of the boilers having to be fired with coal; but in the Cleveland district there was always a surplus of gas from the furnaces, beyond what was wanted for the stoves and for firing the boilers. With regard to scaffolding, the experience at Millom had been that this was generally partial, the furnace having been sometimes found to "hang" at one side, which was attributed

to a cold wind blowing at the time on that side. When a scaffolding took place, the furnace would go on working in an unsatisfactory manner in consequence for several days at a time, before it would come right again.

Mr. CROSSLEY believed the explanation suggested in the paper as to the cause of scaffolding in the hæmatite furnaces was the correct one, namely the very small size of the ore put into the furnaces, in consequence of which it was apt to get deposited somewhat unequally in different parts of the furnace and prevent the regular ascent of the gases at those parts. In this way the material probably became cemented together into large pieces, which came down on the boshes and then produced "scaffolding." He had not had any experience of a scaffolding lasting for days together, as had been alluded to in other hæmatite furnaces; in some instances he had known scaffoldings last for twelve or even eighteen hours, but a slip had then taken place and the furnace had righted itself within a remarkably short time. This was one difference between the hæmatite and the Cleveland furnaces, the latter being a considerable time in recovering themselves after a scaffolding of any considerable duration; whereas he had found in the hæmatite district, as soon as the slip had taken place, the furnace would in a very few hours be working again with its wonted regularity.

The PRESIDENT enquired what was considered to be the reason of the failure of the hæmatite furnace which had been referred to as having been reduced in height.

Mr. CROSSLEY said the furnace referred to was one of 75 feet height, recently built at the Barrow Iron Works, the diameter at the boshes being only the same as in the furnaces of 67 feet height at Askam, namely 19 feet; and the difficulties experienced in that case were to be attributed he considered to not increasing the diameter in proportion to the height, and also to using a much smaller charging bell than was suitable for so high a furnace. The difficulties attending the compact nature of the hæmatite ore were thus increased by the want of greater area of open space in the furnace for ensuring the uniform passage of the ascending gases between the pieces of the materials in all parts of the furnace; and

the effect of the narrow furnace was to cause the gas to creep up at the sides of the furnace or any other part which might happen to be rather more open than the rest.

Mr. T. WHITWELL mentioned that the Consett Iron Co. in the county of Durham had put up about four years ago a close-topped furnace of 70 feet height, for working a close and rich mixture of ore similar to that described as used at Askam. The Consett furnace was 20 feet diameter at the boshes, with a charging bell of 10 ft. 6 ins. diameter; and it was tried with a mixture of one third hæmatite ore from the Whitehaven district and two thirds Cleveland ore, and afterwards with a mixture of hæmatite ore and forge cinder averaging 56 per cent. of metallic iron. The pressure of the blast was $4\frac{1}{2}$ lbs. per square inch, and the temperature 850° Fahr. The furnace however did not work well, and left off driving for upwards of ten days; the attempt had therefore to be abandoned, and the height of the furnace had been cut down 15 feet, leaving it 55 feet high, when it worked well on the mixture that it had previously refused. He understood that an open-topped furnace of 70 feet height had been put up at the West Cumberland Hæmatite Iron Works, Workington, in which the gas was taken off through a centre tube inserted in the furnace throat, so as to admit of seeing the level of the materials in the furnace and ensuring the charging being done with regularity; the temperature of the blast was 750° to 800° , and the pressure $4\frac{1}{2}$ lbs. The furnace was intended to make Bessemer iron, and began by making a little grey; but it did not do well and soon went down to white iron, after which it could not be got back again to grey. After a year's unsuccessful trial it had had to be cut down to the height of the other furnaces in the district, namely 55 feet, and at that height it was now working well, making Bessemer iron. The last attempt which had been made at working a hæmatite furnace of more than the ordinary height was the one at the Barrow Iron Works that had been referred to, with a furnace of 75 feet height and 19 feet diameter at the boshes, having a charging bell 10 ft. 6 ins. diameter; but the furnace not being found to work well had since been reduced to 61 feet height.

The consumption of coke per ton of iron made in the Askam furnaces seemed to him high, inasmuch as at the furnace at Consett, of 55 feet height and 20 feet diameter at the boshes with a charging bell 10 ft. 6 ins. diameter, the consumption was only $17\frac{1}{2}$ cwts. over a period of six months, the furnace producing 400 tons of iron per week, of which 84 per cent. was grey forge iron, while the quantity of white iron did not exceed 2 per cent., and in one instance no white iron was made for a period of more than 26 weeks. A larger furnace had also been subsequently erected at Consett, of 22 ft. 6 ins. diameter at the boshes and 20 ft. 6 ins. diameter at 9 feet below the charging plates, with a 12 ft. 6 ins. bell; this furnace however took about 2 cwts. more coke per ton of iron, and the reason appeared to be that the upper part of the furnace was too large, and it was accordingly intended to alter it by making the lining taper from 22 ft. 6 ins. diameter at the boshes to 15 feet at the top just below the bell, that being the size of furnace which had given the best results. Considering that at Consett, with 1350° temperature of blast and a material containing only 48 per cent. of metallic iron, 84 per cent. of grey forge iron had been made without interruption during a period of more than six months, with a consumption of only $17\frac{1}{2}$ cwts. of coke per ton of iron, he did not understand how it was that the furnaces at Askam, using a richer material containing 58 per cent. of metallic iron, should require so much as $20\frac{3}{4}$ cwts. of coke per ton to make grey forge iron. It was also curious that, while the temperature of the escaping gases from the Consett furnace of 55 feet height was 478° Fahr. with the blast supplied at 1350° , the temperature of the gas from the Askam furnaces of 67 feet height was as much as 730° , though that of the blast was not more than 970° .

Mr. E. BARTON observed that, in reference to the short supply of gas which had been mentioned as being obtained from hæmatite furnaces, he thought this must be owing to some fault in the construction and working of the gas apparatus, irrespective of the closed-top system; he did not see why a close-topped hæmatite furnace should not work as well as a close-topped Cleveland furnace, and the latter always yielded an ample supply of gas for

all heating purposes. At the Carnforth Iron Works, near Lancaster, they had five close-topped hæmatite furnaces, from which abundant gas was obtained, and no coal whatever was used for either boilers or stoves. The charging bells in these furnaces were 8 feet diameter, the furnaces themselves being built with a parallel throat 12 feet diameter for a depth of 10 feet from the charging level, instead of being narrowed in at the top as was usually the case. The parallel throat he considered a decided advantage, enabling the full benefit to be obtained of regularity in charging a close-topped furnace, as the materials then descended uniformly in the order in which they were charged, and he attributed to this cause the very successful working of the Carnforth furnaces; but when the throat expanded from the top downwards, the materials had to spread themselves laterally as they descended, and thus their original uniform distribution when charged into the furnace became interfered with as soon as ever they began to sink lower in the throat of the furnace. With regard to consumption of coke, he thought the consumption stated in the paper of $22\frac{3}{4}$ cwts. per ton of iron would be a large quantity, if the ore contained as much as the 58 per cent. of metallic iron that had been named; but the mixture actually employed of hæmatite and Irish ores seldom contained more than 50 per cent. of metallic iron, the usual charge in the Carnforth furnaces being nearly 2 tons of ore to make 1 ton of iron; and with that proportion the consumption of coke did not appear to him extravagant in reaching $22\frac{3}{4}$ cwts. per ton.

Mr. CROSSLEY said that, in regard to the deficiency of gas from the Millom furnaces, he did not think the gas given off from the hæmatite furnaces was less valuable or less in quantity in proportion to the blast used than was the case in the Cleveland district; but at the Millom Works the furnaces were only semi-closed, and therefore a large quantity of gas escaped at the furnace top, representing of course so much fuel lost. At Askam they had not sufficient gas to heat the blast and raise the steam for the blowing engines, and were consequently obliged to use coal for firing the boilers. This was owing however, not to a poor or insufficient supply of gas from the furnaces, but to the faulty construction of

the blowing engines. By introducing a condensing engine the consumption of coal had already been reduced to half what it was some months ago, and he hoped to make such alterations in the blowing and steam cylinders of the present engines as would result in dispensing entirely with the use of coal.

Mr. D. ADAMSON remarked that it was important to enquire, in connection with the failure of high hæmatite furnaces, whether they had had the advantage of all the conditions essential for properly working a close and dense ore such as the hæmatite; and one consideration of primary importance was the pressure of blast in both the high and the low furnaces. If it were attempted to work a hæmatite furnace of 75 feet height with no greater pressure of blast than was employed in a furnace 55 feet high, it could not be expected that the gases would pass up so vigorously through the materials in the higher furnace as in the lower. In two hæmatite furnaces of 70 feet height the pressure of the blast had been stated to be $4\frac{1}{2}$ lbs. per square inch; and if in other high furnaces the blast pressure was not sufficient to ensure the efficient passage of the gases through all parts of the furnace, he thought it was not the height of the furnace that was at fault, but the want of proper mechanical arrangements for supplying the requisite pressure of blast. In his own experience he had found that, in addition to all the other conditions necessary to be observed for working ores charged in small pieces, the pressure of the blast must be increased in proportion to the density of the ore or its degree of closeness in the furnace. Irregularity of charging was also a source of difficulty in the working of high furnaces; for if the coke and limestone were charged in large pieces at one side of a furnace, whether high or low, and the ore in small pieces at the other side, the materials would descend more rapidly on the more open side, and would cause the other side to "hang;" and any difficulty from this source was of course augmented in the higher furnaces, though due not to their height but to want of proper care in charging the materials with regularity all round the furnace.

The slag from the Askam furnaces making Bessemer iron appeared to him to be carrying with it a large surplus quantity of

lime, the analysis showing 38 per cent. of silica, 10 per cent. of alumina, and as much as 42 per cent. of lime; and he thought for a good fluid slag the proportion of lime should be considerably less, not exceeding 28 or 30 per cent. For by a comparison of a great number of different slags, obtained from blast furnaces in different districts when working well, he had come to the conclusion that the proper proportions of lime, silica, and alumina were attained, when the percentage of lime was equal to the sum of the alumina and half the silica; and this agreed very nearly with what was given in the analysis of slags by Mr. Truran and Dr. Percy as the composition of a free-melting cinder. The slag produced at the Harrington furnaces, near Workington, when working well, contained in samples that had come before him 44 per cent. of silica, 13 per cent. of alumina, and 36 per cent. of lime, which very closely agreed with the above proportion, since $13 + \frac{44}{2} = 35$ per cent. of lime. According to this proportion the percentage of lime for the Askam slag would be $10 + \frac{38}{2} = 29$ per cent. of lime, showing the slag to contain at present 13 per cent. excess of lime, thereby loading the furnace with an increase of dead burden and injuring the heating power of the gas by the production of an undue quantity of carbonic acid. In South Staffordshire the proportion he had named was very closely adhered to, the slag from the furnaces in that district having very generally an approximate composition of about 40 per cent. of silica, 10 per cent. of alumina, and 30 per cent. of lime, when working native materials. If the same proportions were more carefully followed in regulating the charges of blast furnaces generally, by not allowing an excess of lime, he believed the result would be to keep the hearth in order, and neither choke the furnace with an excess of lime, nor run off the metal in the state of white iron.

Mr. J. B. PEASE observed that the furnace of 70 feet height at the West Cumberland Hæmatite Iron Works, which had been referred to, could hardly be adduced as a fair example of the working of a hæmatite furnace of that height, because the circumstances under which the attempt was made in that case were exceptional and unfavourable to a successful result. The furnace had originally

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been built only 55 feet high, and 17 ft. 6 ins. diameter at the boshes, and was closed by a charging bell only 6 ft. 9 ins. diameter, which was too small a size to enable the furnace to work satisfactorily. It was subsequently raised to 70 feet, for which height the diameter of 17 ft. 6 ins. at the boshes was probably too small. Moreover the steam lift by which the furnaces were fed being only 55 feet high, the materials had to be raised from the gallery of the lift by special apparatus to the top of the higher furnace, and it was found this could not be done quickly enough for charging the furnace with sufficient rapidity to enable it to turn out the work expected. Another reason why it failed was that a different material was used in this furnace, the product being intended for another purpose, and the working was not satisfactory. The increased height was therefore abandoned, and the furnace cut down again to its original height of 55 feet; but he had no doubt a hæmatite furnace of 70 to 75 feet height would succeed as well as the lower furnaces working the ore of the Whitehaven district; and that a high furnace with closed top would be worked satisfactorily and with more economy than with the open top usually adopted in furnaces working that ore. In regard to the difficulty which had been alluded to of securing proper charging of the limestone, the general practice in Cleveland was to calcine the whole of the ore before it entered the furnace, and in some cases the limestone also was charged into the calcining kiln together with the ironstone, which produced a better mixing of the materials than could be attained when the limestone was charged raw into the furnace. This was the plan introduced at the Tees Iron Works, Middlesbrough, where it had been found successful.

Mr. D. ADAMSON enquired whether any explanation could be given of the difference between the Carnforth and the Millom furnaces in respect to the supply of gas obtained from them. At Carnforth he believed condensing engines were employed, and if those at Millom were non-condensing they would no doubt require one third more gas for raising steam than the condensing engines; which might account for the deficiency of gas in the one case,

without any material difference existing in the working of the furnaces themselves.

Mr. W. CLAY replied that not much coal was required to be used for the boilers at the Millom furnaces, but the deficiency of gas could not be accounted for by the construction of the engines, as they were condensing engines of the best kind, with cylinders 104 inches diameter. There were only five boilers working at once, two or three of which were fired with coal, and the others as well as all the hot-blast stoves were fired with gas. Perhaps the high temperature of blast obtained in the stoves, amounting to 900° Fahr., might partly account for there not being gas enough for all the boilers; and another reason might be the fact of the furnaces being only semi-closed.

Mr. I. LOWTHIAN BELL observed that, with regard to the question of the height of blast furnaces, there could be no doubt that great height in the abstract was a disadvantage to all furnaces, because greater difficulty was necessarily encountered in forcing the blast through the greater height of superincumbent materials in a high furnace than in a low one. On the other hand, in order to avoid waste of fuel, a certain altitude of furnace was necessary for extracting the sensible heat from the escaping gases, and for deoxidising the ore in the higher parts of the furnace, before it came down into the hearth. It was indispensable that the gases should be allowed to remain in contact with the ore until these objects had been effected, and the time required for reducing one kind of ore was different from that necessary for another. The Cleveland ironstone being particularly refractory was among the last to succumb to the action of the gases, and consequently required to be worked in the highest furnaces. In some of the Styrian charcoal furnaces on the contrary, those at Eisenerz for instance, the ore charged in at the top of the furnace gave in $4\frac{1}{2}$ hours afterwards excellent grey forge iron, with a consumption of only 13 or 14 cwts. of charcoal per ton, the height of the furnaces being only from 35 to 40 feet. This was attributable not to any particular advantage in the use of charcoal, for 1 lb. of Durham coke was worth 1 lb. of the

best charcoal ever made for furnace work, and it was a mistake to imagine that charcoal was a nearer approach to pure carbon than coke was, the fact being that the purest charcoal employed for smelting iron contained generally about 15 per cent. of foreign matter. But the rapid smelting in the Styrian furnaces was due to the circumstance that the ore under treatment was very much more susceptible to reduction than either the Cleveland ore or the hæmatite of the Cumberland district, being a rich spathose ore, containing 50 per cent. of iron; it was indeed very similar in point of richness to the particular mixture of hæmatite ore that was used at Carnforth. The question therefore had to be determined by actual experience in each case, as to what was the height of furnace required for each variety of ore; and while the object was to arrive at such a height as would enable the furnaces to perform their required work with the least consumption of fuel, it was important, if height was in itself an evil though a necessary one, to take care that the proper limit of height was not exceeded, because every foot above the height absolutely required was a clear disadvantage. From information obtained respecting the working of the hæmatite furnaces, his own opinion was that about 55 feet height would be found sufficient for their duty. With regard to the cause of scaffolding, which had been attributed to the gases ascending more readily through certain portions of the furnace and leaving the materials to accumulate in other parts, this was an explanation which might apply to particular cases; but he did not think the origin of scaffolding had yet been ascertained with anything like certainty in the majority of instances of its occurrence. In respect to the consumption of fuel in blast furnaces, as affecting the quantity of gas that could be obtained from the furnace for heating purposes, the latter was in direct proportion to the quantity of fuel burnt, and was therefore reduced with any diminution in the consumption of fuel; but at the same time there was a corresponding diminution in the requirements for which the gas was wanted, as regarded both the quantity and the temperature of the blast; and he accordingly considered it was a matter of indifference whether a

rich or a poor ore was being worked, as in either case, within certain limits, the gas evolved from the furnace would be found sufficient for raising the necessary supply of steam and heating the blast to the required temperature.

Mr. CROSSLEY said he quite concurred in the remarks which had been made as to the high hæmatite furnaces never having been tried previously under all the conditions necessary for the successful working of furnaces of that height. But because under circumstances more or less unfavourable the high furnaces had hitherto failed in the hæmatite district, it was not reasonable to infer that they would always fail; and on the contrary he believed that, when the conditions necessary for their good working were duly observed, it would be found that the larger furnaces would be attended with the same advantages and good results in the hæmatite district as had been the case in Cleveland. For at the present Askam furnaces of 67 feet height, using $22\frac{3}{4}$ cwts. of coke per ton of Bessemer pig, the temperature of the escaping gases was as high as 730° Fahr., and they contained only 13 per cent. of carbonic acid, the materials, both ore and limestone, being charged cold into the furnace, without having been calcined; whereas in the Ferryhill furnace of 105 feet height, it had been found possible to reduce the temperature of the escaping gases to 312° Fahr. with an increase of carbonic acid to 15 per cent., which was due solely to the greater height of the furnace. With these results in the Cleveland district he was led to infer that larger hæmatite furnaces would similarly be attended with considerable advantages in increased economy of fuel, resulting from reduction in the temperature of the escaping gases and increase in the proportion of carbonic acid which they contained.

The PRESIDENT was sure it would be generally agreed that the attempt now being made by the author of the paper to introduce into the hæmatite district the higher furnaces which had been found so advantageous in Cleveland was most praiseworthy; he trusted the efforts to effect thereby an increased economy of fuel in the manufacture of iron would be attended with the success which they

deserved, and he hoped the results of the working of the higher furnaces would be communicated on a future occasion.

He proposed a vote of thanks to Mr. Crossley for his paper, which was passed.

The following paper was then read :—

Fig. 1. *Blast Furnace 67 feet high at Askam.*

Fig. 3. *New
Blast Furnace
75 feet high
at Askam.*

Scale 1/200th

Fig. 4.
Sectional Plan at YY.

Fig 5. Closed Top
of Askam Furnaces.

Fig. 6. Open - topped Hæmatite Furnace.

Fig. 7. Semi - closed Top of Barrow Hæmatite Furnaces.

Fig. 8. Sectional Plan.

Scale $\frac{1}{100}$ th

(Proceedings Inst. M. E. 1871.)

10 5 0 10 20 Feet.

MANUFACTURE OF HÆMATITE IRON.

Plate 41.

Spiral - Tube Water - Tuyere and Tuyere - Breast.

Fig. 9. *Back Elevation.*

Fig. 10.
Longitudinal Section.

(*Proceedings Inst. M. E. 1871.*)

Scale $\frac{1}{8}^{th}$

0 5 10 15 20 Inches.