

March 1st, 1853.

JAMES MEADOWS RENDEL, President,
in the Chair.

THE following candidates were balloted for and duly elected :—
James Barton, as a Member ; James Collins, Robert Ogilvie,
Arthur Wightman, and George Wilkie, as Associates.

No. 889.—“On the increased Strength of Cast Iron, produced
by the use of improved Coke.” By FREDERICK CRACE
CALVERT ; with a Series of Experiments, by WILLIAM
FAIRBAIRN, M. Inst. C.E.

It must be well known to all who are acquainted with the manufacture of iron, that in the ratio of the rapidity of its production, is its deterioration in quality, and it is one of the objects of the present paper to explain the causes of this action.

When charcoal is employed in the blast furnace, the produce is about 2 tons of iron in 24 hours, whilst by the use of coke, or coal and hot blast, from 20 to 30 tons can be smelted in the same time ; and it may be doubted, whether the iron-masters are not more inclined to regard the quantity, than by strict attention to the best methods of production, or to the proportions of the materials employed, to improve the quality of the iron produced. Indeed, complaints have been lately made, by the consumers, as to the very inferior quality of the iron now supplied to them, compared with that of former years, and, unless some change be made, it is to be feared, that the trade may pass from their hands into the workshops of the Continent.

The Author's principal object, in this paper, is to direct the attention of iron-masters to the importance of conducting the different workings of a blast furnace, with more attention to the chemical action, which, he believes, is not at present sufficiently attended to.

In the first place, especial attention is invited to the fact, that ores, widely differing in their relative value and chemical composition, are frequently used in the furnaces, with

the same proportions of lime-stone, cinder, and fuel. Instances have occurred, for example, where a siliceous ore has been used for some hours successively, and then at once replaced by an aluminous, or calcareous iron-stone, without any change being made in the proportions of lime-stone, or coal, which the different qualities of these ores evidently required.

The nature and quantity of flux employed, should vary according to the peculiar chemical composition of the ores, and further, the proportion of fuel, necessary to fuse a vitreous, or calcareous cinder, varies in the same degree, inasmuch as these respectively demand very different amounts of caloric to reduce and liquify them. Hence, the required quality of metal can never be produced with certainty, unless the differing qualities of the iron-stone have been previously examined, and the relative proportions of flux and fuel regulated accordingly.

If due care were observed in working, so as to maintain a proper admixture of the materials, identical results would almost invariably be obtained. When the furnace-men wish to produce a softer metal, they are enabled to do so, by adding more fuel for the same weight of ore and flux, and although this practice succeeds, when the men are careful, and are attentive in using the same quality of ore and flux, still it seldom gives a positive result, owing to the causes above enumerated.

Some iron-smelters assign, as a reason for the addition of from one to three cwt. of coal, or coke, to the quantity usually employed in each charge, that by so doing, they are adding to the quantity of carbon, which they state to be necessary to produce in the furnace No. 1 instead of No. 3, or No. 4 cast iron. Now, it must be borne in mind, that the difference between the quantity of carbon contained in No. 1 and No. 4 iron is very trifling, even if it can be discovered; and it has been demonstrated, that the chief difference between the two kinds of iron is due, in a great measure, to their molecular condition. In fact, if No. 1 iron be melted, and cooled rapidly, it will assume the appearance of No. 3, or even of No. 4 iron. But even, admitting that there is an addition of carbon, and that the excess amounts to even 1 per cent., there would only be 2 cwt. more carbon in 10 tons of No. 1 iron, than there would be found in the same quantity of No. 4 iron; whilst the smelter may have

added, on the top of the blast furnace, 3 or 4 tons of coal, or coke to produce this result.

These facts would appear to demonstrate the correctness of the opinions here expressed, that the additional fuel, used in producing No. 1 iron, is principally required to melt the nearly infusible flux which accompanies the production of that quality of metal.

These remarks, respecting the want of care and attention paid to the chemical composition of the ores which are smelted in blast-furnaces, are equally applicable to the quality of the flux used. Thus, in Scotland, limestones, differing as much as 20 or 30 per cent. in value, are employed in the same proportion for each charge, and instances have occurred where their value has varied 66 per cent. This difference arises principally from their often containing a large proportion of silica, which will render useless an equal weight of lime, when undergoing fusion.

From trials, made on a large scale, for better fluxing the silica contained in the ore, a method was devised which is now adopted, and through which it has been found, that by employing a proper proportion of lime, the furnace works better, and the iron contains less silicium: consequently it is less brittle, and of greater tenacity.

Indeed, it would appear, that the relative proportion of silicium in iron has a great influence on the quality of the metal, and deserves more serious attention than iron-masters have hitherto paid to it.

The following analysis will give an idea of the various quantities per cent. of silicium existing in cast iron:—

White Crude Iron.	Monkland.	Coltness.	Eglington.	Dalmillington.
0·18	1·53	2·69	3·12	4·42

Another exceedingly injurious practice, in the manufacture of iron, is the addition, in the blast furnace, of slag from the puddling furnaces, or the refinery, as the silicate of iron, of which the slag is principally composed, contains large quantities of sulphur and phosphorus, as is shown by the following analysis of puddling-furnace slag, or scoria, at Ebbw-Vale:—

Peroxide of iron	7.14
Protoxide of iron	63.34
Silicic acid	23.20
Phosphorus	3.72
Sulphur	2.60
Lime, magnesia }	Traces.
Alumina and manganese }	
Total	100.00

The manner in which the slag acts injuriously appears to be, that when it is used in the blast furnace, in quantities varying from 28 lbs. to 3, or 4 cwts. to each charge, or round, it agglomerates into one mass, and, gradually descending, is melted, before it has reached a depth of 20 feet ; it then trickles through the materials in the furnace, and if it meets with lime, it is fluxed,—but if not, it travels on, until it comes into contact with the iron, as formed near the tuyere, and thus becomes incorporated with it, rendering it impure, brittle, and of inferior quality.

The effect of the use of such slag was greatly modified at Ebbw-Vale, by breaking it into small pieces, of one inch cube and under, and mixing these lumps intimately with broken quicklime, previous to their introduction into the furnace, so that when they arrived at a melting heat in the furnace, these pieces of slag came into immediate contact with the quick-lime, which was thus enabled to act upon the silica, liberating the oxide of iron.

Before passing to the fuel, the consideration of which forms the principal object of this paper, it is necessary to observe, that when hot blast is used, more care should be taken to maintain a regular temperature in the hot-blast apparatus, particularly at night, when the master, or manager is not present, to exercise control over the workmen. Therefore, great advantage would result from the more general employment of a simple kind of pyrometer, similar to that used at Coltness. It consists of a rod of iron, having one of its ends fixed in the wall, and after traversing the air-heating furnace, acting with the other end, upon a lever connected with a needle, so as to indicate on a dial, by its expansion, the temperature of the furnace. In addition to this, if the other end of the needle were lengthened, so as to move a smaller needle, traversing in a contrary direc-

tion, and so enclosed in a box, as to be out of the reach of the workman, it could be made to indicate the maximum and minimum heat of the furnace, during any given period.

A better mode of enregistering the speed of the engine which furnishes the blast, would be advantageous, and it would be well to employ the combustion of the gases from the top of the blast furnace, as is generally done on the Continent, and as is also successfully applied at the Coltness iron-works, in roasting Clay-band iron ore, and in generating the steam power required to drive the blast engines, and at the Ebbw-Vale works, not only for the last-named purpose, but also as fuel for the air-heating apparatus.

It is now necessary to direct attention to the injurious action which impure fuel has on the quality of the iron, and principally that fuel which contains sulphur; for in the ratio of the quantity of sulphur existing in the coal, or coke, will a relative proportion find its way into the cast iron, and render it "red short." It is, therefore, highly advantageous, that the fuel should be freed from sulphur, before it is employed in the blast furnace, or before it can possibly impart to the cast iron the sulphur it contains.

The presence of either sulphur, phosphorus, arsenic, or silicium is always injurious, and it is chiefly owing to these heterogeneous substances, that the English iron is inferior to the Swedish; and although this fact is generally known, still it is submitted, that it has never been so clearly demonstrated as in the examples now laid before the Institution; for these examples are the first which have been obtained, in which the influence of sulphur, or phosphorus can be duly appreciated, as the same iron is seen with, or without these injurious substances; and the marked difference existing between the Monkland malleable iron, made from cast iron, prepared with coal, as compared with the malleable iron obtained with coal and the improved process, is shown. In fact, this last iron, from which the sulphur has been removed, is found, on comparing it with some best French and German malleable irons, made with wood-charcoal, to be quite equal to them in every respect.

These improvements which have been effected practically, at a very small cost, are carried out in the following manner:—

If the blast furnace is worked entirely with coal, chloride of

sodium is added with it, as it is introduced into the blast furnace; or a better result is obtained by working the furnace with coal and coke, the latter having been prepared, by mixing with the coals, either previously to, or whilst they are being introduced into the coke oven, a proportion of chloride of sodium, varying from one-half to 3 per cent. During the process of coking, a chemical action takes place, and the coke is deprived of a great portion of the sulphur,—care being taken, that in its preparation an excess of the chloride should be used, in order to act on the sulphur of the coal and of the ore, if, from its quality, it should be found to contain any. Thus, it follows, that if only coke was employed in the blast furnace, as is generally the case in Staffordshire, the improvement would be still more manifest.

This opinion is entertained from the results obtained, in conjunction with Mr. Fairbairn, on iron melted in the same cupola with purified coke, as compared with the products from the ordinary coke made from the same coal, but without the purifying process.

The coke prepared by the process alluded to, does not emit any sulphurous fumes, like the ordinary coke, when taken out of the ovens, nor does it, when extinguished with water, give off the unpleasant odour of sulphuretted hydrogen; and no sulphurous acid gas is liberated, during the operation of melting iron, nor when used in locomotives. On the Blackburn division, of the Yorkshire and Lancashire Railway, the coke, so purified, is used daily in all the locomotives, at an additional cost of one penny per ton.

The action of the chloride of sodium is as follows: when coal is first subjected to heat, in a coke oven, the bisulphuret of iron is decomposed into sulphur, which distils, or is converted into sulphurous acid and protosulphuret of iron, which remain in the coke. The latter is acted upon by the chloride of sodium, producing chloride of iron and protosulphuret of sodium. Here, a second chemical reaction ensues, the protochloride of iron is decomposed into a subperchloride of iron—and the chlorine gas, thus liberated, reacts on the sulphuret of sodium, giving rise to chloride of sodium and to chloride of sulphur, which is disengaged, so that the prepared coke contains less sulphur than the ordinary coke. But admitting, even, that

a small portion remains, it will be in the state of sulphuret of sodium, which will not yield any of its sulphur, during combustion, but will pass into the cinders of the blast-furnace, or of the cupola and into the ashes of the fire-box of the locomotive, and thus the injurious effect of the sulphur upon the copper of the fire-box, on the brass tubes of the boiler, and on the iron bars, generally, is prevented.

Nor are these the only benefits, arising from this process of preventing the combustion of the sulphur, for it must be remembered, that the sulphurous acid fumes are carried over the tops of the carriages and on to the tarpaulings of the goods trains, and are there converted into sulphuric acid, which must contribute, in no small degree, to the present rapid decay of the material.

There is an easy experiment, which will leave no doubt of the complete decomposition of the protosulphuret of iron being effected by the agency of chloride of sodium; it is, by calcining, for two hours, in a porcelain crucible, at an intense red heat, a mixture made with one equivalent of the above substances, and two equivalents of chloride of sodium, and the result will be, that there will be found, as a residuum, subperchloride of iron and no trace of sulphuret of iron. This result must appear worthy of consideration, for if the chloride of sodium decomposes the sulphuret of iron in the crucible, it must have the same effect upon the sulphuret of iron in the coal, whilst it is being transformed into coke, or on the sulphuret of iron which exists in the coal, when used for smelting iron, or even, when it is found in the cast iron, while being fused in the blast-furnace, or cupola.

The effect is also satisfactorily proved, by the analyses of the Dalmillington iron, from which a large quantity of sulphur and phosphorus had been removed, by the application of the chloride of sodium in the blast-furnaces, worked entirely with coals.

SULPHUR in DALMILLINGTON IRON.

Without the Process.	With the Process.
Per Cent. 0·95	Per Cent. 0·218
• •	0·208

STRENGTH of 1 Inch square BARS;—4 feet 6 inches between the Bearings.

	Without the Process.	With the Process.
	487	556
	456	525
	487	544
	470	562
	• •	569

Similar results have been obtained at the Monkland furnaces, worked entirely with coals.

SULPHUR in MONKLAND IRON.

	Without the Process.	With the Process.
	Per Cent. 0.39	Per Cent. 0.15

STRENGTH of BARS 1 Inch square;—4 feet 6 inches between the Bearings.

	Without the Process.	With the Process.
	579	627
	576	655

Special attention is directed, to the analyses of the Eglinton iron, which has been employed, in a series of experiments conducted by Mr. Fairbairn personally, in order to ascertain what improvement could be effected in cast iron, when melted in a cupola, with coke prepared by the improved process, as compared with iron, so melted with coke from the same coal, but made in the ordinary way.

SULPHUR in EGLINTON IRON.

Eglinton Pig Iron.	Melted in the Cupola with ordinary Coke.	Melted in the Cupola with purified Coke.
Per Cent. 0.336	Per Cent. 0.281	Per Cent. 0.191

The above results clearly show, that the iron has lost a great portion of the sulphur which it contained, previously to its

being subjected to the action of the purified coke; and as to the increase of strength, Mr. Fairbairn's experiments have shown, that the remarkable improvement effected in the cast iron by melting, is to be ascribed to the use of purified coke.

Much depends, not only on the quality but the quantity of fuel used in the melting process, and it would appear, that a useless, if not a destructive expenditure of coke, is frequently the result of the management, or rather the mismanagement of the furnaces in Lancashire and other parts of the North where coal is cheap; indeed, if the same economy and care were observed in those districts, as is exercised in London and in the South, where fuel is expensive, a much cheaper and better description of iron might be produced.

In corroboration of these remarks, the following carefully conducted experiments, made by Mr. Fairbairn, upon iron melted in the cupola by means of the purified coke, accompanied with a comparison of the same iron, melted by the ordinary coke, are laid before the Institution.

“Experiments on the Strength of Cast Iron smelted with Purified Coke,” by WILLIAM FAIRBAIRN, M. Inst. C.E.

Since the introduction of the use of hot blast and the great economy which that process has effected, in the smelting of iron ores, great uncertainty has been experienced, as to the quality of the metal produced. It is not intended to affirm, that the use of heated blast *per se* does certainly deteriorate the quality of the iron so produced; but, there can be no hesitation in stating, that it places in the hands of the iron-maker great facilities for the reduction of inferior ores, and where coal is used instead of coke, a great proportion of sulphur, which is not vaporized, or oxidized during the process, combines with the iron and not only injuriously affects the cohesive power of its crystalline structure, but seriously injures the density and the formation of its molecular construction. It is correctly observed by Mr. Crace Calvert, it is scarcely possible to conceive “the injurious action which impure fuel has on the quality of the iron, and principally that fuel which contains sulphur, for in the ratio to the quantity of sulphur existing in

the coal, or coke, so will a relative proportion find its way into the cast-iron and render it red short."

Under all the circumstances, it has been repeatedly proved, that the presence of sulphur and phosphorus, either in the blast furnace, or the cupola, is exceedingly deleterious, and produces the most injurious effects upon the tenacity of the crystalline products. Any process, therefore, by which these substances can be removed, or their combination be prevented, will greatly enhance the value of the iron, and afford much greater certainty, as regards uniformity of strength and all those properties which constitute increased powers of resistance, and increased facilities for its application to the varied requirements of the useful arts.

For some years past, great difficulty has been experienced, in obtaining sound castings, from a quality of iron which has all the appearance of being perfectly good; but which, on being fused, exhibits a combination of slag, or scoria and earthy matter, which enters into the moulds and produces large masses of unsound metal, evidently mixed with other substances, entirely destroying the uniformity of its crystalline texture, and producing a spongy porous casting, which in some cases crumbles into dust. Some irons of this kind are not only destructive to the objects for which they are intended, but seriously affect the art as well as the profits of the founder, by the number of 'wasters' that are produced.

To determine the merits of any particular process, when compared with others, it is essential to establish some known principle, by which the products of that process can be fairly and honestly tested. To arrive at correct results in the present case, it is necessary to ascertain in what consists the difference between the iron produced from one description of coke, as compared with the results of the use of another description; and also to show wherein consists the improvement, or deterioration thus effected; the flux and other conditions of the furnace being the same. For these objects it is only necessary to direct attention to the following summary of results, which at once determines the advantages peculiar to the new process and the superior quality of the iron, melted with the improved coke, as regards its increase of strength.

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2 B

Taking the mean of the whole experiments the following conclusions are arrived at :

The mean breaking weight of the bars per square inch, melted with the purified coke, is	lbs. 515·5
The mean breaking weight of the bars per square inch, of the same iron, melted with the ordinary coke	427·0
	<hr/>
	or 88·5

in favour of the castings produced from the improved coke, being in the ratio of 515 : 427, or nearly as 5 : 4.

Taking the mean of all the experiments, the power of resisting impact, would appear to be in the ratio of 798·5 : 755·5 or 43·0 lbs. in favour of the bars melted from the ordinary coke. The bars from the common coke exhibiting less rigidity in the crystalline structure, and a greater amount of flexure, when submitted to a transverse strain.

The results thus obtained from identically the same iron, melted, as nearly as possible, under the same circumstances, but with coke of different degrees of purity, are not only satisfactory as respects the improvement effected ; but the comparatively small cost at which the purifying of the coke can be effected is a point of importance, and is a main reason for bringing the subject under the notice of the Institution.

A short description of the apparatus by which the results were obtained may be useful, as it exhibits the advantages of this method of experimenting, by the substitution of actual weights for the lever, which cannot in every case be depended upon.

The apparatus consists of a strong frame, with a wheel and screw fixed in the centre of the cross beam, from which is suspended the scale, with the load intended to break the bar to be experimented on, which latter rests on two cast-iron brackets screwed on the standards, at the exact distance of 4 feet 6 inches asunder.

Having fixed the bar, the weight of the scale is gently lowered upon the middle of the bar, and having ascertained the

deflection by a graduated scale of inches and parts, inserted between the bar and the gauge, the whole weight is then raised clear of the bar by the screw, when the set, or defect of elasticity, is determined. In this way the bars are successively loaded with weights, varying from 56 lbs. to 28 lbs. and 14 lbs. at a time, until fracture ensues.

EXPERIMENTS.

To determine the relative strength of Bars of cast-iron, 1 inch square, smelted by Mr. Calvert's purified and by common coke; the distance between the supports being in all cases 4 feet 6 inches.

EXPERIMENT I,—Bar No. 1.

Cast from Eglinton, No. 4 iron, fused by purified coke. Depth of Bar .97 inch; width .96 inch,—4 feet 6 inches between the supports.

No. of Experiment.	Weight laid on in lbs.	Deflection in Inches.	Deflection-load removed.	REMARKS.
Scale.				
1	31	+		
2	87	.19		
3	143	.36		
4	199	.52		
5	255	.68		
6	311	{ .75 .88 }	..	{ Weight removed and again restored, without any apparent defect of elasticity; deflection increased to .88.
7	367	1.08		
8	423	{ 1.28 1.35 }	..	Weight removed and again restored.
9	437	1.38		
10	451	1.43	..	Apparently no change in its elasticity.
11	465	1.49		
12	479	1.53		
13	493	..	..	Broke in the middle.
		Ultimate Deflection = 1.57		

RESULTS reduced to bars 1 inch square.

Mean Sectional Area .965 inch No. 1 Bar.	<i>b</i> Breaking-weight in lbs.	<i>d</i> Ultimate Deflection in Inches.	Product <i>b</i> × <i>d</i> or Power of resisting Impact.
4 feet 6 inches between the supports.	511	1.62	828.8

The appearance of the fracture of this iron was of a clear grey colour, remarkable in its uniformity of texture and in its crystalline structure.

EXPERIMENT II,—Bar No. 2.

Cast from Eglinton, No. 4 hot-blast iron, fused by the purified coke. Depth of Bar 1·04 inch—width ·95 inch,—4 feet 6 inches between the supports.

No. of Experiment.	Weight laid on in lbs.	Deflection in Inches.	Deflection-load removed.	REMARKS.
Scale.				
1	31	+		
2	87	·05		
3	143	·20		
4	199	·33		
5	255	·48		
6	311	·65	..	No change in elasticity.
7	367	·77		
8	423	·98		
9	451	1·06	..	No change.
10	465	1·10		
11	472	1·12		
12	479	1·14		
13	484	1·15		
14	487	1·16		
15	490	1·17		
16	495	1·18		
17	499	1·20		
18	504	1·22		
19	509	1·23		
20	513	1·24		
21	518	1·26	·660	
22	523	1·27		
23	528	1·30		
24	532	1·32		
25	537	1·33		
26	541	1·35		
27	546	1·37	·175	
28	551	1·40		
29	558	..	..	Broke near the middle of the bar.
		Ultimate Deflection = 1·47		

RESULTS reduced to bars 1 inch square.

No. 2 Bar. — 4 feet 6 inches between the Supports.	<i>b</i> Breaking- weight in lbs.	<i>d</i> Ultimate Deflection in Inches.	Product <i>b</i> × <i>d</i> or Power of resisting Impact.
	560	1·47	823·20

The metal appeared to have run exceedingly close, and exhibited a compact granulated structure, with a light-grey colour.

EXPERIMENT III,—Bar No. 3.

Cast from Eglinton, No. 4 hot-blast iron, fused by the purified coke.
Depth of Bar, 1.32 inch; width .972 inch,—4 feet 6 inches between the supports.

No. of Experiment.	Weight laid on in lbs.	Deflection in Inches.	Deflection-load removed.	REMARKS.
Scale.				
1	31	+		
2	87	.01		
3	143	.17		
4	199	.40		
5	255	.57		
6	311	.72		
7	367	{ .87 .87 }	..	{ After weight had been taken off and restored.
8	423	1.02		
9	451	1.13		
10	465	1.16		
11	472	1.19		
12	479	1.20		
13	484	1.23		
14	487	1.24		
15	490	1.25		
16	495	1.27		
17	500	1.275		
18	505	1.29		
19	509	1.30		
20	513	1.32		
21	518	1.34		
22	523	{ 1.36 1.37 }	.05	{ After weight had been taken off and restored.
23	530	1.37		
24	537	1.41		
25	544	1.43		
26	551	1.46		
27	558	1.46		
28	565	..	..	{ Broken a short distance from the middle of the bar.
		Ultimate Deflection = 1.47		

RESULTS reduced to bars 1 inch square.

No. 3 Bar. — 4 feet 6 inches.	b Breaking-weight in lbs.	d Ultimate Deflection in Inches.	Product $b \times d$ or Power of resisting Impact.
	563	1.47	827.61

This iron presented all the characteristics of that in the last experiment; of great density, and exceedingly compact in its crystalline appearance; colour the same as No. 2.

The result of the experiments on No. 2 and No. 3 bars indicated iron of a high order as to strength, and which might be considered equal to the strongest cold-blast.

EXPERIMENT IV,—Bar No. 4.

Cast from Eglinton, No. 4 hot-blast iron, fused by ordinary coke. Depth of Bar 1·015 inch; width, ·96 inch,—4 feet 6 inches between the supports.

No. of Experiment.	Weight laid on in lbs.	Deflection in Inches.	Deflection-load removed.	REMARKS.
Scale.				
1	31	+		
2	87	·26		
3	143	·43		
4	199	·66		
5	255	·97		
6	311	{ 1·27 1·29 }	e·046	{ Weight removed, increase of deflection ·02.
7	367	1·67		
8	395	1·88	·17	
9	409	1·96		
10	423	..	..	{ Broke after sustaining the weight about three minutes.
		Ultimate Deflection = 2·02		

RESULTS reduced to 1 inch square.

No. 4 Bar. — 4 feet 6 inches between the Supports.	b Breaking- weight in lbs.	d Ultimate Deflection in Inches.	Product b × d or Power of resisting Impact.
	423	2·04	873·12

Here there was a comparatively weak iron, with increased deflexion, and superior in its power to resist impact. It was much more porous in the fracture, than the iron melted by the purified coke, and exhibited a rim of a closely granulated texture round the outer edge of the bar; the colour was dull grey, with an appearance of minute particles of sand in combination with the iron.

EXPERIMENT V,—Bar No. 5.

Cast from Eglinton, No. 4 hot-blast iron, fused by ordinary coke. Depth of Bar 1·01 inch; width ·96 inch;—4 feet 6 inches between the supports.

No. of Experiment.	Weight laid on in lbs.	Deflection in Inches.	Deflection-load removed.	REMARKS.
Scale.				
1	31	+		
2	87	·34		
3	143	·55		
4	199	·87		
5	255	1·16		
6	311	{ 1·57 }	·17	Weight removed.
7	367	{ 1·59 }	· ·	Broke in the middle.
		Ultimate Deflection = 1·89		

RESULTS reduced to 1 Inch square.

No. 5 Bar. — 4 feet 6 inches between the Supports.	b Breaking- weight in lbs.	d Ultimate Deflection in Inches.	Product b × d or Power of resisting Impact.
	380	1·946	739·12

The colour of the fracture was the same as in Experiment IV.

On comparing the results of the two Experiments, IV. and V., it will be observed, that a considerable difference exists between the bars, both as regards their respective powers of resistance to a transverse strain, and their power of resisting impact. These discrepancies often appear in castings, and not unfrequently perplex the Engineer, as well as the workman, to account for the variable increase, or diminution of power which occur in the various castings from the same melting; the rate of cooling, the difference of temperature in the metal, when the moulds are run, as well as other causes, may, however, be considered to lead to the variable condition of the solidified mass.

EXPERIMENT VI, —Bar No. 6.

Cast from Eglinton, No. 4 hot-blast iron fused by ordinary coke. Depth of bar, 1·00 inch; width, ·96 inch,—4 feet 6 inches between the supports.

No. of Experiment.	Weight laid on in lbs.	Deflection in Inches.	Deflection-load removed.	REMARKS.
Scale.				
1	31	+		
2	87	·22		
3	143	·43		
4	199	·70		
5	255	1·00		
6	311	{ 1·38 1·40 }	·06	{ Weight removed and again restored; increased deflection, ·02.
7	339	1·55		
8	343	1·68	·18	
9	377	1·80		
10	391	1·90	·26	
11	415	2·00		
12	422	· ·	· ·	Broke near the centre of the bar.
		Ultimate Deflection = 2·01		

RESULTS reduced to bars 1 inch square.

No. 6 Bar — 4 feet 6 inches between the Supports.	<i>b</i> Breaking- weight in lbs.	<i>d</i> Ultimate Deflection in Inches.	Product of <i>b</i> × <i>d</i> or Power of resisting.
	430	2·04	877·2

This bar had all the characteristics of that in Experiment iv. It exhibited nearly the same amount of strength and deflection, and might, in other respects, be considered a fair average quality of iron.

The colour of the fracture appeared more luminous than No. 4 and 5 bars, but was not so sparkling as those fused by the purified coke.

EXPERIMENT VII,—Bar No. 7.

Cast from Eglinton, No. 4 hot-blast iron fused by ordinary coke. Depth of bar, 1.09 inch; width, .972 inch;—4 feet 6 inches between the supports.

No. of Experiment.	Weight laid on in lbs.	Deflection in Inches.	Deflection-load removed.	REMARKS.
Scale.				
1	31	+		
2	87	.10		
3	143	.16		
4	199	.37		
5	255	.52		
6	311	.68		
7	367	{ .84 .86 }	..	{ After weight had been removed and again restored.
8	423	1.02		
9	451	1.12		
10	465	1.20		
11	479	{ 1.23 1.24 }	..	,, ,, ,,
12	486	1.26		
13	493	1.29		
14	493	1.31		
15	503	1.33		
16	508	1.35		
17	513	..	..	{ This bar was rather defective, being blown at one place.
		Ultimate Deflection = 1.36		

RESULTS reduced to bars 1 inch square.

No. 7 Bar. — 4 feet 6 inches between the Supports.	b Breaking- weight in lbs.	d Ultimate Deflection in Inches.	Product of b × d or Power of resisting Impact.
	497	1.12	651.07

The ultimate strength, deflection, and power of resisting impact was not so great in this iron as in Nos. 1, 2, and 3 bars, which were cast from the same coke, and although superior in its resistance to a transverse strain, it was nevertheless deficient in its power to resist impact. In colour it was a lightish grey, with a sharp hard exterior, and a crystalline structure.

EXPERIMENT VIII,--Bar No. 8.

Cast from Eglinton, No. 4 hot-blast iron, fused by ordinary coke. Depth of Bar, 1.09 inch; width, .93 inch;—4 feet 6 inches between the supports.

No. of Experiment.	Weight laid on in lbs.	Deflection in Inches.	Deflection-load removed.	REMARKS.
Scale.				
1	31	+		
2	87	.10		
3	143	.23		
4	199	.36		
5	255	.44		
6	311	.72		
7	367	.93	..	No change.
8	423	1.01		
9	451	1.20		
10	465	1.26		
11	479	{ 1.33 } { 1.34 }	.062	Weight again restored.
12	486	1.36		
13	493	1.38	.12	
14	498	1.40		
15	503	1.42		
16	508	1.43	.18	
17	513	1.44	..	Slightly.
18	518	Broke.	..	Another defective bar, same as last.
		Ultimate Deflection = 1.45		

RESULTS reduced to bars 1 inch square.

No. 8 Bar. — 4 feet 6 inches between the Supports.	<i>b</i> Breaking- weight in lbs.	<i>d</i> Ultimate Deflection in Inches.	Product of <i>b</i> × <i>d</i> or Power of resisting Impact.
	511	1.432	730.73

There appeared to be no particular difference in the appearance of this bar and the last (No. 7). It exhibited the same granulated fracture, and was of as near as possible equal, if not greater density. It was a rather stronger iron than No. 7, and presented increased power of resistance to impact.

EXPERIMENT IX,—Bar No. 9.

Cast from Eglinton, No. 4 hot-blast iron, fused by purified coke. Depth of Bar, 1·03 inch; width, ·968 inch;—4 feet 6 inches between the supports.

No. of Experiment.	Weight laid on in lbs.	Deflection in Inches.	Deflection-load removed.	REMARKS.
Scale.				
1	31	+		
2	87	·20		
3	143	·34		
4	199	·53		
5	255	·73		
6	311	·94		
7	367	{ 1·16 } 1·18	·061	Loss of elasticity.
8	423	1·40	·124	This bar also was slightly defective.
9	451	Broke.		
		Ultimate Deflection = 1·49		

RESULTS reduced to bars 1 inch square.

No. 9 Bar. — 4 feet 6 inches between the Supports.	b Breaking- weight in lbs.	d Ultimate Deflection in Inches.	Product of $b \times d$ or Power of resisting Impact.
	451	1·49	671·99

No. 9 bar broke $4\frac{1}{2}$ inches from the centre, having a slight flaw in that part of the casting; it would not, however, have borne many more lbs., as the defect was only just perceptible. The appearance of the fracture was the same as before.

EXPERIMENT X,—Bar No. 10.

Cast from Eglinton, No. 4 hot-blast iron, fused by ordinary coke. Depth of Bar, 1·04 inch; width, ·941 inch;—4 feet 6 inches between the supports.

No. of Experiment.	Weight laid on in lbs.	Deflection in Inches.	Deflection-load removed.	REMARKS.
Scale.				
1	31	+		
2	87	·20		
3	143	·37		
4	199	·55		
5	255	·76		
6	311	1·00	·12	
7	367	1·28	··	No change; weight again restored.
8	423	1·54	·18	
9	451	Broke.		Perfectly sound at the fracture.
		Ultimate Deflection = 1·64		

RESULTS reduced to bars 1 inch square.

No. 10 Bar. — 4 feet 6 inches between the Supports.	b Breaking- weight in lbs.	d Ultimate Deflection in Inches.	Product of b × d or Power of resisting Impact.
	455	1·65	750·75

In this experiment there was increased strength, with diminished deflection, as compared with the bars previously cast from the ordinary coke.

EXPERIMENT XI,—Bar No. 11.

Cast from Eglinton, No. 4 hot-blast iron, out of the same furnace, and fused by ordinary coke. Depth of bar, 1·04 inch; width, ·941 inch;—4 feet 6 inches between the supports.

No. of Experiment.	Weight laid on in lbs.	Deflection in Inches.	Deflection-load removed.	REMARKS.
Scale.				
1	31	+		
2	87	·30		
3	143	·50		
4	199	·74		
5	255	1·00		
6	311	1·30	·12	Loss of elasticity ·02.
7	367	{ 1·62 1·64		
8	423	Broke.	··	After resisting the weight a few seconds.
		Ultimate Deflection = 1·87		

RESULTS reduced to bars 1 inch square.

No. 11 Bar. — 4 feet 6 inches between the Supports.	<i>b</i> Breaking- weight in lbs.	<i>d</i> Ultimate Deflection in Inches.	Product of $b \times d$ or Power of resisting Impact.
	427	1.887	805.74

Great similarity appears to exist among all the bars cast from the ordinary coke. This was evidently a weaker iron, in its power of resistance to a dead weight, but superior in its power to resist impact, when compared with the same iron fused by the purified coke.

EXPERIMENT XII,—Bar No. 12.

Cast from Eglinton, No. 4 hot-blast iron, fused by ordinary coke. Depth of Bar, .973 inch; width, .944 inch;—4 feet 6 inches between the supports.

No. of Experi- ment.	Weight laid on in lbs.	Deflection in Inches.	Deflection- load removed.	REMARKS.
Scale.				
1	31	+		
2	87	.30		
3	143	.50		
4	199	.70		
5	255	.90		
6	311	1.17	.13	No change after weight being restored.
7	367	1.43		
8	395	1.52	.17	
9	423	Broke.	..	All sound.
		Ultimate Deflection = 1.62		

RESULTS reduced to bars 1 inch square.

No. 12 Bar. — 4 feet 6 inches between the Supports.	<i>b</i> Breaking- weight in lbs.	<i>d</i> Ultimate Deflection in Inches.	Product of $b \times d$ or Power of resisting Impact.
	441	1.69	745.29

The last three bars experimented upon were almost identical in colour and appearance; they, however, wanted the sharp granulated texture which indicated the appearance of those melted by the purified coke, and they were also defective in

the rigid character which that iron represents, when subjected to a transverse strain.

The following additional experiments have been made subsequently to those given in the body of the Paper :—

EXTRACTS from Results obtained at the Works of Messrs. JOHN GALLOWAY and SON, Engineers, Manchester, on the 27th February, 1853.

All the bars were 1 inch square, and the distance between the supports was 4 feet 6 inches.

IRON.	ORDINARY COKE.		PURIFIED COKE.	
	Breaking-weight.	Deflection.	Breaking-weight.	Deflection.
Gartsherry	514	1.44	549	1.29
Shelton	598	1.27	652	1.50
Mixture of Irons . . .	612	1.35	661	1.49
Mean . .	575	..	621	..

Improvement 8 per cent.

EXTRACTS from Results obtained at Messrs. Fox and HENDERSON's, London Works, near Birmingham, 17th June, 1853.

All the bars were 1 inch square, and the distance between the supports was 4 feet 6 inches.

IRON.	ORDINARY COKE.		PURIFIED COKE.	
	Breaking-weight.	Deflection.	Breaking-weight.	Deflection.
Gibbon's No. 3	448	1.06	493	1.25
	428	1.03	520	1.30
	..	..	528	1.23
Mean . .	435	..	514	..
Mixture of Iron	428	1.11	468	1.22
	425	1.11	460	1.16
	400	1.24	450	1.13
Mean . .	417	..	459	..

Showing a per centage of

18 per cent. in No. 3 iron; and

10 per cent. in the mixture of iron, when fused by the purified coke.