AN

EXPERIMENTAL INQUIRY

INTO THE

Strength and other properties

OF

ANTHRACITE CAST IRON,

BEING A

CONTINUATION OF A SERIES OF EXPERIMENTS ON BRITISH IRONS, EROM VARIOUS PARTS OF THE UNITED KINGDOM.

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Read 17th November, 1840.

In March, 1837, I laid before the Society a detailed series of experiments on the strength and other properties of cast iron, collected from the different works in Great Britain. Since that time a description of iron, entitled anthracite, has been introduced into the market. The name anthracite was first applied to carboniferous formations by the French; it is derived from the Greek word *anthrax*, coal. The iron is made either wholly or in part from anthracite fuel, and in most cases the best qualities are obtained from the raw coal alone, excited by the hot blast.

At some of the Welsh iron works, coke and anthracite coal in certain proportions have been tried, and at others a mixture of bituminous and anthracite coal; but in almost every instance, I believe, the products have been of an inferior quality, and it is only since the introduction of the hot blast that anthracite coal alone has been rendered available in the reduction of the ores. It is now, however, generally adopted in the anthracite districts, and several works have recently been erected for the manufacture of iron by this new process.

Before entering upon the examination of the specimens experimented upon, I would first premise a few observations on the nature and properties of the fuel from which they were produced.

Mr. W. R. Johnson, Professor of Chemistry and Natural Philosophy, of Pennsylvania College, Philadelphia, has paid great attention to this subject, and by a careful analysis of the American coal, has given the products of the anthracite formation, as found in Luzerne county, Pennsylvania. The American anthracites so nearly resemble those of our own country, both as regards their properties and appearance, that I shall, before concluding this part of the subject, make a few extracts from Professor Johnson's inquiries, in order to compare them with similar carbonaceous deposits found in the Swansea basin, and other parts of South Wales. In the latter districts, as at Aberavon, Hirwin, &c., the beds of anthracite alternate with the bituminous formations, sometimes composing the uppermost strata, but in most cases underlaying the bituminous coal. In some positions they pass into very thin laminæ, and in others, the layers are so intermixed as to form the coal *en masse*. They, however, vary in quality, according to the district where they are found. The lower veins of the Bute colliery, at the Hirwin and Plymouth iron works, according to Mr. Mushet, are partly anthraciteous, containing a greater or lesser degree of anthracite matter, accompanied with certain proportions of bitumen or carburetted hydrogen.

The coal at the Yniscedwyn and Ystalyfera works, in the Swansea valley, is entirely anthracite, containing nearly the same proportions of carbon as are exhibited in Professor Johnson's experiments on the American specimens.

The purest Welsh anthracite coal, such as the Yniscedwyn, Ystalyfera, and the lower stratum of Neath Abbey, contains about 90 per cent of carbon, and the remaining ten parts are composed of carburetted hydrogen, carbonic oxide, and some earthy matter. Out of two specimens sent me from the Ystalyfera works, the following results were obtained—

Loss at a red heat, yielding a little carburetted hydrogen	5.4
Ashes, greyish white	4.6
Carbon	90.0
	100.0

From this description of fuel, we derive the best qualities of anthracite iron.

At the iron works of Vezille, in the canton of Launure, near Grenoble, large sums of money (500,000 francs) were expended in the construction of works, and in making experiments for the fusion of the earthy carbonate of iron, by the anthracite of Launure. These works were in progress from 1824 to 1828, when they were abandoned, the proprietors being no longer able to contend against obstacles which seemed insurmountable. Many interesting results were nevertheless obtained from the experiments made at the time.

The ashes of this anthracite gave the following constituents, the analysis being a mean of experiments on a large quantity:

Silex	58.4
Alumina	40.0
Lime	1.6
	100.0

M. Robin gives the depth of the beds as varying from five to twenty-one yards: the coal is a perfect black, has a slight metallic lustre, and its fracture is conchoidal, when made in the mass.—Its density is very great, and by reason of its great compactness, it kindles with difficulty, and consumes slowly.

The same properties are observable in the analysis of the Welsh, and also of the American anthracites, all of which exhibit peculiar features, as to their density, and their resistance to combustion.

These coals will pass through a smelting furnace, exposed to intense heat, for a period of 48 hours, with no other apparent change than their surfaces being slightly calcined. When these specimens are broken, the interior fractures exhibit the same black lustre as is observable in the raw material.

Out of three specimens of American anthracite coal, analyzed by Professor Johnson, the following products were obtained—

"Specimen No. 1, when heated to a temperature sufficient to expel the water which it contains, without decomposition, lost per cent		1.915
When the dried coal is ignited to redness for some time in a close vessel, it yields carbonic oxide, and carburetted hydrogen with a small portion of sulphur		5.068
The remaining fixed carbon is		88.187
Earthy matter 4.83 per cent., viz.,	Silica	2.589
	Alumina	1.772
	Peroxide of iron	.270
	Lime	.138
	Magnesia	.052
	Protoxide of Manganese	.009
		100.000

From the latter numbers it will be perceived, that of the fixed ingredients or ashes of this coal, 100 parts will be composed—

Of Silica	53.604
„ Alumina	36.687
„ Peroxide of iron	5.590
„ Lime	2.857
„ Magnesia	1.076
„ Protoxide of Manganese	.186
	100.000

The ashes of this coal are of a yellowish white, or very light buff colour, and very bulky."

In speaking of No. 1, specimen, Mr. Johnson describes it as a compact structure, giving conchoidal fractures in all directions, apparently indifferent to the surface of deposition, which are manifested only by alternating lines or seams of bluish black, and jet black, which mark the successive layers. He states the appearance to give the idea, that the surfaces have been in a great measure obliterated, while the whole mass was, from some cause, in a semi-fluid state. The specific gravity is stated at 1.591 or 99½ lbs. to the cubic foot.

No. 2, specimen, experimented upon by Professor Johnson, gave a specific gravity of 1.574, or 98⅓ lbs. to the cubic foot, and yielded 85.909 per cent. of carbon.

No. 3, specimen, was found to have a specific gravity of 1.55 or 96¾ lbs to the cubic foot; and carbon, not volatile at a white heat, equal to 90.705 per cent.

The above analysis not only shows the composition of this description of fuel, but exhibits the density and compactness of its structure. It also affords evidence of its fitness for the smelting furnace, and its adaptation to purposes where a great heating power is required. This description of coal, although well known for many years to the miners and iron manufacturers of South Wales, has, nevertheless, been much neglected, and its valuable, as well as economical properties almost entirely overlooked by them, from the circumstance of their inability to burn it.

Mr. Martin, in 1804, made the first attempt to use anthracite for the fusion of iron ore, but without any satisfactory results; twenty years afterwards, other trials were made to form a conglomerate coke, composed of anthracite and bituminous coal, but these, like the former, were unsuccessful. Mr. Crane, of the Yniscedwyn iron works, was the first to introduce, exclusively, anthracite for the purpose of smelting; first by its introduction to the cupola, and subsequently to the smelting furnace, by the use of the hot blast. Mr. Price of Neath Abbey, also made several experiments on this mineral, and found that about 8 cwt. of bituminous coal, coked in ovens, mixed with 25 cwt. of anthracite, gave one ton of iron; effecting a saving greater than anything yet accomplished by the hot blast, and the common coal.

The Ystalyfera ores are reduced in the same manner as those at Yniscedwyn, chiefly or entirely by anthracite coal in the raw state. The process is as nearly as possible, the same as that used at coke furnaces, the charge being, coal, 5 cwt., and mine (according to the working of the furnace, and the quality of iron to be produced), from 6 to 8 cwt—the average proportion of limestone as flux—being nearly one-third of the quantity of mine used.

Mr. Thomas Bevan, of the Ystalyfera works, in handing me specimens of the iron ore, stated that he attaches no importance to the specific gravity of the minerals. Some of the ores have, however, been analyzed, three of which are as follows—

No. 1,	Specific	Gravity,	3.358,	yielding	iron	28.70	per cent.
2,	„	„	3.417,	„	„	20.35	„
3,	„	„	3.521,	„	„	38.50	„

From the above it will be seen that although the specific gravity of all the specimens is nearly alike, yet the degree of richness varies considerably; No. 3 specimen yielding nearly double the quantity of iron to No. 2.

The analysis of the specimens sent by Mr. Bevan, is as annexed.

	No. 1. Rhonson.	No. 2. Pin Melin.
Silicate of alumina	31.60	20.60
Alumina	.50	
Lime	1.70	.10
Magnesia...	2.55	.25
Iron	25.10	34.95
Manganese	1.19	.80
Sulphur	.55	
Carbonic acid and water	28.65	32.65
Oxygen with iron	7.20	9.95
Ditto with manganese	.68	.46
Total found	99.72	99.76
Loss	.28	.24
	100.00	100.00

Having ascertained the constituents of the anthracite formations, and their fitness for the smelting furnace, it now becomes necessary to direct attention to the properties of the iron made from this fuel. On a former occasion forty-nine different sorts of the British irons were experimented upon; they were carefully tested, and the results (accompanied with considerable detail) have since been printed in the society's Memoirs. The anthracite irons have undergone a similar treatment; and the experiments having been conducted under the immediate superintendence of my friend, Mr. Hodgkinson, I have no hesitation in vouching for the accuracy with which they were made.

The bars having been cast as before, 1 inch square, were placed on supports 4 feet 6 inches asunder; and by the usual method of suspending weights from the middle, the strengths, deflections, elasticities, &c. were obtained, as follows—

No. 1.

WELSH IRONS.

Yniscedwyn Anthracite, No. 1, Pig Iron, Hot Blast.

Experiment 1st. Depth of bar ...... 1.017; Breadth of do. ...... 1.014; Distance between supports ...... 4ft. 6in.; Weight of bar 5 feet long, 15lbs. 6oz.			*Experiment 2nd.* Depth of bar ...... 1.026; Breadth of do. ...... 1.010; Distance between supports ...... 4ft. 6 in.; Weight of bar 5 feet long, 15lbs. 6¼oz.			*Experiment 3rd.* Depth of bar ...... 1.023; Breadth of do. ...... 1.015; Distance between supports ...... 4ft. 6in.; Weight of bar 5 feet long 15lbs. 10oz.		
Weight in lbs.	Deflection in inches.	Deflection load removed.	Weight in lbs.	Deflection in inches.	Deflection load removed.	Weight in lbs.	Deflection in inches.	Deflection load removed.
28	.077	.005	28	.075	+	28	.065	+
56	.150	.013	56	.150	.015	56	.142	+
112	.330	.022	112	.301	.021	112	.290	.011
224	.656	.070	224	.649	.066	224	.645	.055
336	1.065	.135	336	1.043	.130	336	1.053	.122
392	1.320		448	1.516	.250	448	1.550	.245
448	1.568	.255	483	broke		483	1.720	
459	broke					490	1.760	broke
∴ Ultimate deflection, =1.616.			∴ Ultimate deflection, 1.664.			∴ Ultimate deflection, = 1.800.		

Results reduced to those of Bars 1. 00 inch square.

	Specific Gravity.	Modulus of elasticity in lbs. per square inch.	Breaking weight (b.)	Ultimate deflection (d.)	Product, $b \times d$ or power of resisting impact.
Experiment 1st, bar 4ft. 6in. between supports......	7.086		437.66	1.643	719.1
Experiment 2nd, bar 4ft. 6in. between supports......	7.118	13,459,200	454.29	1.707	775.5
Experiment 3rd, bar 4ft. 6in. between supports......	7.029	14,023,600	467.89	1.841	861.4
Mean....................................	7.078		453.28	1.730	785.3

The Anthracite No. 1 Iron, when examined by the microscope, exhibits nearly the same appearance in the fracture as the Bute specimen, in No. XI. Table of my former experiments. It is rather fine-grained for a No. 1, Iron, porous in the centre, and slightly tinged with a grayish blue colour. Judging from the experiments, I should consider this a useful iron, as it works freely, and possesses considerable powers to resist a transverse strain.

No. II.

WELSH IRONS.

Yniscedwyn Anthracite, No. 1, Pig Iron, Hot Blast.

Experiment 1st. Depth of bar .... 1.027 Breadth of do....... 1.006 Distance between supports........2ft. 3in.			*Experiment 2nd.* Depth of bar ...... 1.017 Breadth of do....... 1.009 Distance between supports........2ft. 3in.			*Experiment 3rd.* Depth of bar ...... 1.025 Breadth of do. ...... 1.011 Distance between supports........ 2ft. 3in.		
Weight in lbs.	Deflection in inches.	Deflection load removed.	Weight in lbs.	Deflection in inches.	Deflection load removed.	Weight in lbs.	Deflection in inches.	Deflection load removed.
112	.025		112	.040		112	.040	
224	.060		224	.081		224	.080	
336	.105		336	.125		336	.122	
448	.152		448	.167		448	.164	
560	.202		560	.205		560	.207	
672	.250		672	.250		672	.250	
784	.315		784	.300		784	.310	
896	.390		896	.375		896	.365	
			952	.410		952	broke	
			980	.440				
			1008	.455				
			1036	broke				
Broke with laying the weight, 896lbs., on again.			∴ Ultimate deflection, =.470.			∴ Ultimate deflection, =.393.		

Results reduced to those of Bars 1.00 inch square.

	Specific Gravity.	Modulus of elasticity in lbs. per square inch.	Breaking weight ($b.$)	Ultimate deflection ($d.$)	Product $b \times d$, or power of resisting impact.
Experiment 1st, bar 2ft. 3in. between supports......			897.2	.440	394.8
Experiment 2nd, bar 2ft. 3in. between supports......			992.7	.478	474.2
Experiment 3rd, bar 2ft. 3in. between supports......			892.1	.403	359.5
Mean....................................			927.3	.440	409.5

No. III.
WELSH IRONS.
Yniscedwyn Anthracite, No. 2, Pig Iron, Hot Blast.

Experiment 1st. Depth of bar........ 1.031 Breadth of do ...... 1.014 Distance between supports ....4ft 6in Weight of bar 5 feet long, 15lbs 13oz			*Experiment 2nd.* Depth of bar ...... 1.025 Breadth of do ...... 1.026 Distance between supports .... 4ft 6in Weight of bar 5 feet long, 15lbs 12oz			*Experiment 3rd.* Depth of bar........ 1.015 Breadth of do ...... 1.023 Distance between supports .... 4ft 6in Weight of bar 5 feet long, 15lbs 10oz			*Experiment 4th.* Depth of bar........ 1.027 Breadth of do ...... 1.016 Distance between supports 2ft 3in			*Experiment 5th.* Depth of bar........ 1.025 Breadth of do........ 1.025 Distance between supports ....2ft. 3in.		
Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed
28	.065		28	.062		28	.066		224	.065		112	.038	
56	.132	+	56	.130	+	56	.134	+	336	.090		224	.076	
112	.254	.011	112	.263	.013	112	.271	.015	448	.130		336	.110	
224	.540	.040	224	.560	.033	224	.575	.043	560	.165		448	.141	
336	.862	.074	336	.867	.071	336	.900	.075	672	.210		560	.190	
448	1.220	.140	448	1.230	.131	448	1.272	.145	784	.260		672	.224	
476	1.310		504	1.422		476	1.365		896	.308		784	.265	
504	1.415	.185	522	broke		504	1.485	.188	1008	.345		896	.308	
						529	broke		1064	.384		1008	.355	
									1120	.410		1106	broke	
									1176	.440				
									1180	broke				
Broke, with laying the weight, 504lbs, on again; great care was used.			∴ Ultimate deflection =1.484.			∴ Ultimate deflection =1.593.			∴ Ultimate deflection =.442.			∴ Ultimate deflection =.396.		

Results reduced to those of Bars 1.00 inch square.

	Specific Gravity	Modulus of elasticity in lbs per square inch	Breaking weight (b)	Ultimate deflection (d)	Product $b \times d$, or power of resisting impact
Experiment 1st, bar 4ft. 6in. between supports ...	7.088	15,620,400	467.6	1.449	677.50
Experiment 2nd, bar 4ft. 6in. between supports ...	7.118	15,172,750	484.26	1.521	636.56
Experiment 3rd, bar 4ft. 6in. between supports ...	7.079	15,208,850	501.9	1.617	811.57
Mean....................................	7.095	15,334,000	484.6	1.529	708.54
Experiment 4th, bar 2ft. 3in. between supports ...			1101.1	.498	548.35
Experiment 5th, bar 2ft. 3in. between supports ...			1027.0	.406	416.96
Mean....................................			1064.0	.452	482.65

No. 2, is similar in colour to No. 1, Iron, but closer-grained, and accompanied with the usual appearance of compact crystals round the edges of the fracture. It is a free-working Iron, and ranks well in the scale of strengths.

No. IV.
WELSH IRONS.
Yniscedwyn Anthracite, No, 3, Pig Iron, Hot Blast.

Experiment 1*st.* Depth of bar........ 1.010 Breadth of do....... 1.008 Distance between supports........4ft. 6in. Weight of bar 5 feet long, 15lbs. 7oz.			*Experiment 2nd.* Depth of bar........ 1.018 Breadth of do....... 1.010 Distance between supports........4ft. 6in. Weight of bar 5 feet long, 15lbs. 9oz.			*Experiment 3rd.* Depth of bar........ 1.024 Breadth of do....... 1.012 Distance between supports........4ft. 6in. Weight of bar 5 feet long, 15lbs. 11oz.			*Experiment 4th,* Depth of bar........ 1.012 Breadth of do....... 1.015 Distance between supports........2ft. 3in.			*Experiment 5th.* Depth of bar........ 1.025 Breadth of do....... 1.006 Distance between supports........2ft. 3in.		
Weigbt in lbs	Deflection in inches	Deflection load removed	Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed
28	.065	+	28	.064	+	28	.060		112	.035		112	.020	
56	.132	.010	56	.125	+	56	.120	+	224	.070		224	.055	
112	.263	.014	112	.255	.010	112	.252	.006	336	.105		336	.090	
224	.555	.032	224	.545	.031	224	.533	.024	448	.140		448	.125	
336	.875	.070	336	.850	.065	336	.838	.055	560	.175		560	.155	
448	1.225	.115	448	1.190	.110	448	1.175	.108	672	.215		672	.185	
504	1.420	.155	504	1.375	.145	504	1.360	.138	784	.250		784	.232	
529	broke		553	broke		532	broke		896	.295		896	.271	
									1008	.340		1008	.323	
									1064	.365		1092	.344	
									1078	broke		1120	.360	
												1124	broke	
∴ Ultimate deflection =1.507,			∴ Ultimate deflection =1.537.			∴ Ultimate deflection =1.453.			∴ Ultimate deflection =.371.			∴ Ultimate deflection =.362.		

Results reduced to those of Bars 1.00 inch square.

	Specific Gravity	Modulus of elasticity in lbs per square inch	Breaking weight (b)	Ultimate deflection (d)	Product $b \times d$, or power of resisting impact.
Experiment 1st, bar 4ft. 6in. between supports......	7.206	16,179,650	514.5	1.522	783.1
Experiment 2nd, bar 4ft. 6in. between supports ...	7.114	16,264,630	528.3	1.565	826.8
Experiment 3rd, bar 4ft. 6in. between supports ...	7.184	16,138,700	501.3	1.488	745.9
Mean....................................	7.168	16,194,327	514.7	1.525	785.3
Experiment 4th, bar 2ft. 3in. between supports ...			1037.1	.375	388.9
Experiment 5th, bar 2ft. 3in. between supports ...			1063.5	.372	395.6
Mean....................................			1050.3	.373	392.2

This is a rigid strong Iron, finely granulated, and presents an appearance of great uniformity in the fracture. Colour a whitish gray. It is exceedingly dense, of high specific gravity, but not particularly hard, as it yields with comparative ease to the chisel and file.

No. V.

WELSH IRONS.

Ystalyfera Anthracite, No. 1, Pig Iron, Hot Blast.

Experiment 1*st.* Depth of bar........ 1.035 Breadth of do ...... 1.050 Distance between supports .... 4ft 6in Weight of bar 5 feet long, 15lbs 14oz			*Experiment* 2*nd.* Depth of bar........ 1.035 Breadth of do ...... 1.053 Distance between supports .... 4ft 6in Weight of bar 5 feet long, 15lbs 15oz			*Experiment* 3*rd.* Depth of bar ...... 1.027 Breadth of do ...... 1.048 Distance between supports .... 4ft 6in Weight of bar 5 feet long, 15lbs 11oz		
Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed
28	.075		28	.073	+	28	.075	+
56	.152	+	56	.152	.012	56	.155	.012
112	.320	.024	112	.333	.040	112	.338	.032
224	.728	.090	224	.730	.113	224	.760	.095
336	1.240	.205	336	1.250	.210	336	1.285	.216
392	1.550	.300	448	1.922	.453	392	1.610	
448	1.910	.442	476	broke		448	2.000	.480
476	2.105					473	broke	
501	broke							
∴ Ultimate deflection, =2.279.			∴ Ultimate deflection, =2.090.			∴ Ultimate deflection, =2.174.		

Results reduced to those of Bars 1.00 inch square.

	Specific Gravity	Modulus of elasticity in lbs per square inch	Breaking weight (b)	Ultimate deflection (d)	Product $b \times d$, or power of resisting impact
Experiment 1st, bar 4ft. 6in. between supports ...	7.000	11,835,300	445.4	2.359	1050.7
Experiment 2nd, bar 4ft. 6in. between supports ...	6.974	11,340,806	421.9	2.163	912.6
Experiment 3rd, bar 4ft. 6in. between supports ...	7.007	11,490,800	427.9	2.233	955.5
Mean....................................	6.992	11,555,635	434.7	2.252	972.9

The Ystalyfera No. 1 Iron (first sample) is rather weaker than the Yniscedwyn of the same class; it is, however, very ductile, and possesses great power of resisting impact. In this respect it is the best Iron I have yet experimented upon, the mean ultimate deflection from three experiments being 2.252. The deflection of this Iron is greater than that of any other recorded in my former experiments. It has considerable elastic power, and bends through a large space before it breaks. Colour a bluish gray.

No. VI.

WELSH IRONS.

Ystalyfera Anthracite, No. 1, Pig Iron, Hot Blast.

Experiment 1*st.* Depth of bar........ 1.025 Breadth of do ...... 1.038 Distance between supports 2ft 3in			*Experiment* 2*nd.* Depth of bar........ 1.016 Breadth of do ...... 1.037 Distance between supports.........2ft 3in			*Experiment* 3*rd.* Depth of bar........ 1.030 Breadth of do ...... 1.037 Distance between supports 2ft 3in		
Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed
112	.045		112	.045		112	.046	
224	.090		224	.093		224	.097	
336	.130		336	.140		336	.149	
448	.180		448	.200		448	.205	
560	.225		560	.270		560	.271	
672	.285		672	.335		672	.345	
784	.353		784	.420		784	.438	
896	.450		896	broke		840	.495	
938	broke					868	.516	
						896	.545	
						910	.561	
						924	broke	
∴ Ultimate deflection, =.486.			∴ Ultimate deflection, =.505.					

Results reduced to those of Bars 1.00 inch square.

	Specific Gravity	Modulus of elasticity in lbs per square inch	Breaking weight (b)	Ultimate deflection (d)	Product $b \times d$, or power of resisting impact
Experiment 1st, bar 2ft. 3in. between supports......			860.1	.498	428.3
Experiment 2nd, bar 2ft. 3in. between supports ...			837.0	.513	429.4
Experiment 3rd, bar 2ft. 3in. between supports ...			839.9	.594	498.9
Mean...........................			845.7	.535	452.2

No. VII.

WELSH IRONS.

Ystalyfera Anthracite, No. 2, Pig Iron, Hot Blast.

Experiment 1*st*. Depth of bar ...... 1.040 Breadth of do. ..... 1.026 Distance between supports ...... 4ft. 6in. Weight of bar 5 feet long, 15lbs 12oz			*Experiment* 2*nd*. Depth of bar ...... 1.022 Breadth of do. ..... 1.046 Distance between supports .... 4ft 6 in Weight of bar 5 feet long, 15lbs 10oz			*Experiment* 3*rd*. Depth of bar ...... 1.018 Breadth of do. ...... 1.041 Distance between supports .... 4ft 6in Weight of bar 5 feet long, 15lbs 9oz		
Weight in lbs.	Deflection in inches.	Deflection load removed.	Weight in lbs.	Deflection in inches.	Deflection load removed.	Weight in lbs.	Deflection in inches.	Deflection load removed.
28	.062	.005	28	.065	+	28	.065	
56	.132	.011	56	.135	+	56	.135	.005
112	.270	.049	112	.294	.014	112	.280	.013
224	.590	.100	224	.632	.050	224	.648	.053
336	.965	.197	336	1.039	.120	336	1.058	.124
448	1.380	.279	448	1.540	.250	448	1.580	.261
504	1.650		473	broke		476	1.732	
522	broke					490	broke	
∴ Ultimate deflection, =1.742.			∴ Ultimate deflection, =1.679.			∴ Ultimate deflection, =1.804.		

Results reduced to those of Bars 1.00 inch square.

	Specific gravity	Modulus of elasticity in lbs per square inch	Breaking weight (b)	Ultimate deflection (d)	Product $b \times d$, or power of resisting impact
Experiment 1st, bar 4ft. 6in. between supports......	7.043	14,149,705	470.4	1.812	852.4
Experiment 2nd, bar 4ft. 6in. between supports ...	7.022	13,432,200	432.9	1.716	742.9
Experiment 3rd, bar 4ft. 6in. between supports ...	7.093	14,337,906	454.2	1.836	833.9
Mean..................................	7.053	13,973,270	452.5	1.788	809.7

Ystalyfera No. 2 Iron (first sample.)—Appearance of the fracture, a dark gray, with the crystals more minute, and in closer contact than in No. 1 specimen. It is rather a soft Iron, easily cut with the chisel or file, and is well adapted for mixing with Irons of greater tenacity.

No. VIII.

WELSH IRONS.

Ystalyfera Anthracite, No. 2, Pig Iron, Hot Blast.

Experiment 1st. Depth of bar .... 1.018 Breadth of do....... 1.031 Distance between supports 2ft 3in			*Experiment 2nd.* Depth of bar ...... 1.022 Breadth of do....... 1.020 Distance between supports 2ft 3in			*Experiment 3rd.* Depth of bar ...... 1.008 Breadth of do. ...... 1.024 Distance between supports 2ft 3in		
Weight in lbs	Deflection in inches	Deflection load removed	Weight in lbs	Deflection in inches	Deflection load removed	Weight in lbs	Deflection in inches	Deflection load removed
112	.032		112	.035		112	.450	
224	.075		224	.075		224	.850	
336	.113		336	.123		336	.132	
448	.160		448	.165		448	.166	
560	.210		560	.211		560	.212	
672	.259		672	.255		672	.262	
784	.322		784	.312		784	.315	
896	broke		896	.375		896	.385	
			1008	.455		952	.424	
			1012	broke in 5 min.		973	broke	
∴ Ultimate deflection, =.385			∴ Ultimate deflection, =.458.			∴ Ultimate deflection, =.439.		

Results reduced to those of Bars 1.00 inch square.

	Specific Gravity	Modulus of elasticity in lbs per square inch	Breaking weight (b)	Ultimate deflection (d)	Product $b \times d$, or power of resisting impact
Experiment 1st, bar 2ft. 3in between supports ...			838.6	.392	328.7
Experiment 2nd, bar 2ft. 3in. between supports ...			949.9	.468	444.6
Experiment 3rd, bar 2ft, 3in. between supports ...			935.2	.443	414.3
Mean....................................			907.9	.434	395.9

No. IX.

WELSH IRONS.

Ystalyfera Anthracite, No. 3, Pig Iron, Hot Blast.

Experiment 1st. Depth of bar........ 1.040 Breadth of do ...... 1.023 Distance between supports .... 4ft 6in Weight of bar 5 feet long, 15lbs 12oz			*Experiment 2nd.* Depth of bar........ 1.005 Breadth of do ...... 1.060 Distance between supports .... 4ft 6in Weight of bar 5 feet long, 15lbs 13oz			*Experiment 3rd.* Depth of bar ...... 1.015 Breadth of do ...... 1.040 Distance between supports .... 4ft 6in Weight of bar 5 feet long, 15lbs 9oz		
Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed
28	.064		28	.070	+	28	.064	
56	.133	.005	56	.145	.006	56	.136	.005
112	.283	.013	112	.304	.015	112	.305	.016
224	.628	.045	224	.665	.044	224	.682	.058
336	1.000	.102	336	1.095	.105	336	1.100	.115
448	1.450	.195	448	1.600	.222	448	1.600	.230
476	1.570	broke	504	1.885	.315	490	1.828	
						504	1.920	broke
Broke whilst taking deflection.			Broke one inch from the centre, with laying on the weight again.			Broke whilst taking deflection.		

Results reduced to those of Bars 1. 00 inch square.	Specific Gravity	Modulus of elasticity in lbs per square inch	Breaking weight (b)	Ultimate deflection (d)	Product, $b \times d$ or power of resisting impact
Experiment 1st, bar 4ft. 6in. between supports......	7.126	13,538,710	430.2	1.633	702.5
Experiment 2nd, bar 4ft. 6in. between supports......	7.143	13,479,205	470.8	1.894	891.7
Experiment 3rd, bar 4ft. 6in. between supports......	7.129	13,292,505	470.4	1.950	917.3
Mean....................................	7.133	13,436,806	457.1	1.825	837.2

Ystalyfera, No. 3, is a dense and closely granulated Iron. Like most other No. 3 Irons, it exhibits great uniformity in its crystaline formation, accompanied with a slight degree of porosity in the centre of the fracture. This is, however, common to every description of Cast Iron, and varies according to the size of the casting. Colour, a whitish gray.

No. X.

WELSH IRONS.

Ystalyfera Anthracite, No. 3, Pig Iron, Hot Blast.

Experiment 1*st.* Depth of bar........ 1.016 Breadth of do ...... 1.035 Distance between supports 2ft 3in			*Experiment* 2*nd.* Depth of bar ...... 1.050 Breadth of do ...... 1.005 Distance between supports 2ft 3in			*Experiment* 3*rd.* Depth of bar .... 1.015 Breadth of do....... 1.040 Distance between supports 2ft 3in		
Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed	Weight in lbs	Deflection in inches	Deflection, load removed
112	.030		112	.035		112	.037	
224	.075		224	.074		224	.078	
336	.122		336	.114		336	.128	
448	.170		448	.160		448	.175	
560	.216		560	.197		560	.220	
672	.260		672	.244		672	.266	
784	.310		784	.298		784	.323	
896	.370		896	.354		896	.385	
1008	.436		1008	.420		945	broke	
1064	.481		1036	broke				
1092	.498							
1106	broke							
∴ Ultimate deflection =.507.			∴ Ultimate deflection =.435.			∴ Ultimate deflection =.434.		

Results reduced to those of Bars 1.00 inch square.

	Specific Gravity.	Modulus of elasticity in lbs. per square inch.	Breaking weight (*b.*)	Ultimate deflection (*d.*)	Product $b \times d$, or power of resisting impact.
Experiment 1st, bar 2ft. 3in. between supports......			1035.2	.515	533.1
Experiment 2nd, bar 2ft. 3in. between supports......			935.0	.457	427.3
Experiment 3rd, bar 2ft. 3in. between supports......			882.0	.441	389.0
Mean........................			950.7	.471	449.8

After the preceding experiments were made, Mr. Richard Evans forwarded from the proprietors of the Ystalyfera iron works, other samples of the iron, Nos. 1, 2, and 3, which, I was informed, were made with anthracite coal alone, whilst the first samples were smelted with anthracite, mixed with a small portion of bituminous coke. In both cases a blast of heated air was used. Feeling desirous of ascertaining the comparative strength of the iron in the two cases, I cheerfully acceded to the wishes of the proprietors, and had experiments made upon the second sample, precisely similar to those made on the first.

No. XI.

RESULTS OF EXPERIMENTS

UPON THE SECOND SAMPLE OF YSTALYFERA CAST IRON, MADE WITH ANTHRACITE COAL.

The results are from bars 4ft. 6in. between the supports, and one inch square exactly.

		Specific Gravity	Modulus of elasticity in lbs	Breaking weight (b)	Ultimate deflection (d)	Product $b \times d$, or power of resisting impact
No. 1, Iron.	Experiment 1st	6.917	14,076,600	378.3	1.385	523.9
	„ 2nd	7.288	14,236,950	398.8	1.451	578.7
	„ 3rd	7.112	14,017,180	370.4	1.330	492.6
	„ 4th	7.075	13,846,950	421.7	1.614	679.6
	Mean	7.098	14,044,420	392.3	1.445	568.7
No. 2, Iron.	Experiment 1st	7.300	15,965,800	521.2	1.733	903.2
	„ 2nd	7.347	15,928,700	491.7	1.502	738.5
	„ 3rd	7.328	15,740,100	434.4	1.283	557.3
	„ 4th	7.059	15,112,400	475.4	1.503	714.5
	Mean	7.258	15,686,750	480.7	1.505	728.4
No. 3, Iron.	Experiment 1st	7.292	18,878,000	491.7	1.304	641.2
	„ 2nd	7.256	17,826,250	525.2	1.421	746.3
	„ 3rd	7.180	17,998,400	494.3	1.275	630.2
	„ 4th	7.381	18,863,050	496.4	1.297	643.8
	Mean	7.352	18,391,425	501.9	1.324	665.4

REMARKS ON THE PRECEDING IRONS.

No. 1 has nearly the same appearance as to colour and porosity in the centre of the fracture, as No. 1, of the first sample: it is a soft, fluid iron, and apparently well adapted for the lighter descriptions of castings.

No. 2 is of greater density than the corresponding number in the first sample; it indicates a strong, compact structure, accompanied with the usual appearance of minute crystals on the outer edges of the fracture. Colour a whitish gray.

No. 3 is rather more compact in its crystalline structure than the No. 3 of the first sample. The fracture presents a greater admixture of white than that of No. 2, and when viewed by the microscope, immediately after fracture, the crystals emit a clear brilliant light.

At the conclusion of my former paper in this volume, I gave a general summary of results comprising the strength and other properties of forty-nine sorts of British irons. They were ranked according to their relative strengths, taken from the mean breaking weights of bars one inch square, placed upon supports 4ft. 6in. asunder. The strongest being marked No. 1, and the others according to their respective ranks in the scale.*

On this occasion it will be necessary to follow the same rule as that formerly used, and to collect the results from the experiments on the anthracite iron, into a similar form.

I have found these summaries of considerable value in judging of the different kinds of iron; and if they were generally used, and taken as a guide by the architect and engineer, I have every reason to hope that improper mixtures, as well as the use of improper material in castings, would be prevented.

* The irons experimented upon were mostly obtained from the makers or their agents; and if any iron should be misrepresented, or not have had full justice done to it, it will afford me great pleasure to rectify the defect or omission.

SUMMARY OF RESULTS

OBTAINED FROM THE PRECEDING EXPERIMENTS ON RECTANGULAR BARS OF ANTHRACITE CAST IRON, EACH BAR BEING REDUCED TO EXACTLY ONE INCH SQUARE.

In the following abstract, the transverse strength, which may be taken as the chief criterion of the value of each Iron, is obtained from the mean of the experiments ; first, on long bars, 4ft. 6in. between supports, and next, on those of half the length, or 2ft. 3in. between supports.

All the other values are deduced from the 4ft. 6in. bars.

No. of Iron in the scale of strength	Names of Irons.	Number of experiments on each	Specific Gravity	Modulus of elasticity in lbs per square inch	Breaking weight in lbs of bars 4ft 6in between supports	Breaking weight in lbs of bars 2ft 3in, reduced to 4ft 6in between supports	Mean breaking weight in lbs (S)	Ultimate deflection of 4ft 6in bars, in parts of an inch	Power of the 4ft 6in bars to resist impact
1	Yníscedwyn, No. 3...............	5	7.168	16,194,327	515	525	520	1.525	785
2	,, ,, 2...............	5	7.095	15,334,000	485	532	508	1.529	709
3	Ystalyfera ,, 3, 2nd do	4	7.352	18,391,425	502		502 } mean	1.324	665 } mean
4	,, ,, 3, 1st do	6	7.133	13,436,806	457	425	441 } 472	1.825	837 } 751
5	,, ,, 2, 2nd do	4	7.258	15,686,750	481		481 } mean	1.505	728 } mean
6	,, ,, 2, 1st do	6	7.053	13,973,270	453	454	454 } 468	1.788	810 } 769
7	Yniscedwyn ,, 1...............	6	7.078	13,741,400	453	464	458	1.730	785
8	Ystalyfera ,, 1, 1st sample	6	6.992	11,555,635	435	423	429 } mean	2.252	973 } mean
9	,, ,, 1, 2nd do	4	7.098	14,044,420	392		392 } 410	1.445	569 } 771

In estimating the value of any particular iron, it must be remembered, that its resistance, or rigidity under strain, is exclusively the criterion of its strength, but not the measure of its utility. Some irons of the very first quality exhibit weakness under strain, but possess, at the same time, great richness and fluidity, accompanied with elastic powers of no ordinary description. For example, the Ystalyfera No. 1, first sample, is an iron of this character, and although inferior to other irons, as respects strength, it has, nevertheless, great flexure, the ultimate deflection being 2.252, which is greater than that of any other iron I have yet experimented upon. In its powers to resist impact, it approaches nearly to the Gartsherrie, Ponkey, and Elsicar irons, the numbers being—

Gartsherrie	No. 3=998	Powers to resist impact.
Ponkey	No. 3=992	
Elsicar	No. 2=992	
Ystalyfera	No. 1=973	

No. 1 of the Ystalyfera second sample, is inferior, both as regards strength, and its powers of resisting impact.

On comparing the results in the last table with those in the List of the General Summary, at the conclusion of my former paper, we find that the iron from the Yniscedwyn works has considerable strength. No. 1 stands as No. 14 in the general summary, and has only two irons of the same number before it. No. 2 stands No. 6 in the list, and is stronger than any other iron of the same number. No. 3 stands No. 5 in the list, having only four others in advance of it.

On the whole, the Ystalyfera iron has less strength than the Yniscedwyn, but the first sample of it possessed toughness in a high degree; it was very flexible, and resisted impact with great tenacity. The second sample was stronger than the first, but offered less resistance to a blow. The mean results from the first and second samples of this iron, give 410, 468, and 472, for the strengths of Nos. 1, 2, and 3 respectively, the first of these standing as No. 45, the second as No. 12, and the third as No. 11, in the General Summary.

It may not be improper to mention, that the parties connected with the Ystalyfera iron works, have had other experiments made upon their own account; the strengths, as given by these experiments, are greater than those obtained from either of the samples which I have received. I am unable to assign the cause of the difference which exists, and can only observe, that the preceding experiments were conducted with the greatest care, and the utmost attention was paid to every circumstance, however minute, in order to obtain correct results.

In conclusion, I would observe, that—judging from the experiments—I consider the use of anthracite coal rather favourable than otherwise to the manufacture of iron ; and provided some well conducted experiments were made to ascertain the requisite proportions of flux and ore to this description of coal, much might be done to improve the quality of the iron, and to bring into useful operation a valuable and important mineral production.