VI.—*Experiments to Determine the Properties of some Mixtures of Cast Iron and Nickel.*

By William Fairbairn, F.R.S.

Read March 9th, 1858.

Some of my chemical friends in London had got an impression from a careful analysis of meteoric iron, that it could be produced artificially by the combination of some of the same elements that were found to exist in the specimen analysed, containing about 2½ per cent of nickel.

In order to determine whether it would be possible to obtain an artificial compound of this nature, and to ascertain the effect produced by mixing a certain proportion of nickel with cast iron, the following experiments were instituted. They consisted, in the first instance, in the extraction of the nickel from the ore which is found in the mines of the Duke of Argyle, near Inverary in Scotland. The metal having then been purified by repeated meltings, was mixed with cast iron in such proportions as to form a compound, containing the same quantity of nickel as the specimen analysed. This was done by melting 2½ per cent of nickel with carefully selected South Welsh cast iron from the works of Blaenarvon and Pontypool. The mixtures were fused in crucibles, and run into ingots or bars, which were then tested in regard to their mechanical powers of resistance to a transverse strain.

This was done with great care, and the results which follow give unmistakeable evidence of the effects produced upon cast iron by an admixture of nickel, however small the quantity of the latter that may be introduced. Meteoric iron is, above all others, the most ductile, and it is recorded by travellers that the Esquimaux have instruments made from this description of iron so ductile that they may be made to bend round the arm. The ingots prepared on the occasion of these experiments were, however, widely different, as their power to resist impact was nearly one half less than in those composed of pure iron.

It is uncertain what might have been the results had the castings produced been treated as cast steel, and hammered out until they were rendered malleable and magnetic. This process was not, however, attempted, as, judging from the appearance of the fracture, they were more likely to crumble under the hammer than attain malleability.

The nickel for these experiments was prepared from the ore, by fusing at a very high temperature in a crucible or steel pot,

30*lbs.* of roasted ore,
5*lbs.* of fine sand,
2*lbs.* of charcoal,
2*lbs.* of lime.

This mixture was kept in the furnace six hours, and then taken out and allowed to cool. The metal was then separated from the slag, and again melted with half its weight of roasted ore and one quarter its weight of green bottle glass ground to powder.

As before, the mixture was kept for six hours, at the temperature of a cast steel furnace. The metal had by the end of that time collected at the bottom of the crucible. It contained about 25 per cent of nickel, and was of sufficient purity to be fused with cast iron. 10*lbs.* of it melted with 112*lbs.* of cast iron gave a mixture containing about $2\frac{1}{2}$ per cent of nickel.

The object of these fusings was to reduce the metallic oxide by means of the charcoal, while the lime and sand removed the oxide of iron, silica, sulphur and other impurities by forming a fusible slag.

Mixtures of nickel with cast iron (No. 1) and Blaenarvon iron (No. 3) and Pontypool iron, each containing about $2\frac{1}{2}$ per cent of nickel, and also some pure Blaenarvon cast iron (No. 1) were cast into bars about one inch square and two feet six inches long, and subjected to the following experimental tests: —

TABLE I. Breaking weights and deflections of bars of cast iron and of alloys of nickel and cast iron, when subjected to a transverse strain.

Experiment I. Cast Iron No. 1, with Nickel.		Experiment II. Pure Cast Iron, No. 1.		Experiment III. Blaenarvon Iron, No. 3, with Nickel.		Experiment IV. Blaenarvon Iron, No. 3.		Experiment V. Pontypool Iron with pure Nickel.	
Section of bar in inches, 1×1.		Section of bar in inches, 1×1.		Section of bar in inches, 1×1.		Section of bar in inches, 1.02×1.07.		Section of bar in inches, 1×1.	
Weight laid on in lbs.	Deflection in inches.	Weight laid on in lbs.	Deflection in inches.	Weight laid on in lbs.	Deflection in inches.	Weight laid on in lbs.	Deflection in inches.	Weight laid on in lbs.	Deflection in inches.
147	0·125	147	0·1	147	0·05	147	0·05		
259	0·175	259	0·155	259	0·1	259	0·1		
315	0·19			315	0·14				
371	0·25	371	0·2	371	0·16	371	0·115	371	0·225
427	0·275			427	6·18	427		427	0·237
483	0·34	483	0·225	483	0·2	483	0·2	483	0·25
539	0·375	539	0·25	539	0·237	539	0·237	539	0·262
				567	0·25	567	0·25		
595	0·41	595	0·31	595	0·255	595	0·262		
		609	0·325						
623	0·425	623	0·33	623	0·277	623	0·275		
637		637	0·35						
Broke with this weight.		651	0·36	651	0·285	651	0·3	651	0·3
		679	0·365	679	0·29	679	0·325	679	0·312
		707	0·367	707	0·3	707	0·337	707	0·325
		721	0·375						
		735	0·4	749	0·325	749	0·362		
		763	0·41	763	0·34			763	0·35
		777	0·425	791	0·425	777	0·375	791	
		791	0·44						
		819	0·46	833	0·45	819	0·4	798	
		847	0·46			847	0·42	Broke with this weight.	
		861		861					
		Broke with this weight.		875		875	0·437		
				Broke with this weight.		917	0·45		
						959	0·5		
						1043	0·525		
						1099	0·575		
						1155	0·675		
						With this weight it remained twenty minutes.			
						1267	0·75		
						Broke after some seconds.			
Ultimate deflection 0·434″		Ultimate deflection 0·47″		Ultimate deflection 0·58″		Ultimate deflection 0·75″		Ultimate deflection 0·366″	

TABLE II. Results reduced to bars 1″ square. Distance between the supports 2′ 3″.

	Breaking weight (b)	Ultimate deflection (d)	Power of resisting impact ($b \times d$)	Strength compared with Blenarvon =1000
Experiment I. bar D. pure Blaenarvon No. 3..........	1131	0·75	848·2	1000
Do. II. „ C. Blaenarvon No. 3 and nickel...	875	0·58	507·5	773
Do. III. „ B. pure cast iron No. 1............	861	0·47	404·7	761
Do. IV. „ A. cast iron No. 1 and nickel.......	637	0·434	276·4	563
Do. V. „ E. Pontypool iron and pure nickel	798	0·366	292·1	705
Mean...............	860	0·52	465·7	760

From the above it is evident that an admixture of nickel in the proportion of 2½ per cent does not increase but diminish the tenacity of cast iron. To what extent it might be improved by augmenting or lessening the proportion of nickel, a more extended series of experiments alone can determine. Mixtures of the two metals in the proportion used in the above experiments are decidedly inferior to the pure metal in their power of resistance to a transverse strain and to impact. In the first and second experiments on Blaenarvon iron there is a loss of nearly one-fifth the strength; or the strength of the pure metal is to that of the mixture as 1000 : 773. And in Experiments III. and IV. with a more fluid iron there is about the same loss, the relative strengths being as 761 : 563; or as 1000 : 740. From these facts it is evident that nickel in the proportion of 2½ per cent seriously injures the strength of cast iron, and moreover has injurious effects on its power of resisting impact, as the columns in the above table indicating those properties clearly show.

It is difficult to account for the serious deterioration and loss of strength which the above experiments indicate. It may probably arise from the improper treatment of the nickel ore during its calcination and subsequent reduction in the crucible. When cast into ingots after the second melting the nickel had not the appearance of a pure metal, but exhibited a dull fracture, as if fine sand or particles of earth had been mixed with the crystals, showing the presence of impurities which it would be almost impossible to get rid of. It remained, therefore, a question for consideration whether the results would be different if nickel, properly prepared and of greater purity, were employed. To clear up doubts on this point a mixture of pure nickel with No. 3 Pontypool iron was made, but the result was a bar of white silvery metal, which broke when the weight of 798*lbs.* was laid on, as will be seen by referring to the Tables above.

I obtained from London a number of other bars, consisting of iron and nickel, which on being submitted to the same tests as before, gave better results than those obtained in the previous experiments when nickel prepared from the ore was employed.

The results obtained from this second series of bars are given in the following table:

TABLE III. Breaking weights and deflections of bars of nickel and cast iron, when subjected to a transverse strain. The bars were about one inch square, and the distance between the supports was two feet three inches.

Experiment VI. Bar F 1 not marked with notches.		Experiment VII. Bar F 2 not marked with notches.		Experiment VIII. Bar G 1 marked with one notch.		Experiment IX. Bar G 2 marked with one notch.		Experiment X. Bar H 1 marked with two notches.		Experiment XI. Bar H 2 marked with two notches.	
Section of bar in inches, 1·02 × 1·02.		Section of bar in inches, 1·02 × 1·02.		Section of bar in inches, 1·02 × 1·02.		Section of bar in inches, 1·2 × 1·2.		Section of bar in inches, 1·15 × 1·15.		Section of bar in inches, 1·15 × 1·15.	
Wght. laid on in lbs.	Deflection in inches.	Wght. laid on in lbs.	Deflection in inches.	Wght. laid on in lbs.	Deflection in inches.	Wght. laid on in lbs.	Deflection in inches.	Wght. laid on in lbs.	Deflection in inches.	Wght. laid on in lbs.	Deflection in inches.
147	0·02	147	0·005	147	0·02						
259	0·06	259	0·05	259	0·06	259	0·06	259	0·06	259	0·08
371	0·1	371	0·1	371	0·12	371	0·08	371	0·1		
427	0·12	427	0·115	427							
483	0·14	483	0·14	483	0·17	483	0·11	483	0·14	483	0·14
539	0·16	539	0·18	539		539	0·155	539	0·165		
595	0·18	595	0·19	595	0·23	595	0·17	595	0·17	595	0·18
623	0·19										
651	0·2	651	0·21	651	0·26	651	0·19	651	0·18	651	0·2
679	0·21	679	0·22								
707	0·22	707	0·23	707	0·29	707	0·2	707	0·19		
735	0·24	735	0·24								
763	0·25	763	0·255	763	0·32	763	0·215	763	0·2	763	0·23
777	0·255										
791	0·26	791	0·27	791							
805	0·265	805	0·28	Broke.		819	0·23	819	0·23	819	0·25
819	0·27	819	0·285			875	0·25	875	0·24	875	0·27
833	0·28	833	0·29			931	0·27	931	0·27	931	
847	0·29	847	8·295			959	0·28	959	0·28	Broke.	
861	0·3	861	0·3			987	0·285	987			
875	0·31	875	0·31			1043	0·3	Broke.			
903		903	0·32			1057	0·31				
Broke.		917	0·325			1071	0·317				
		931	0·33			1099	0·321				
		959	0·345			1127	0·33				
		987	0·355			1155	0·34				
		1015	0·375			1183	0·35				
		1029	0·38			1121	0·36				
		Broke.				1239	0·375				
						1267	0·385				
						1295					
						Broke.					
Ultimate deflection 0·315″		Ultimate deflection 0·38″		Ultimate deflection 0·331″		Ultimate deflection 0·41″		Ultimate deflection 0·286″		Ultimate deflection 0·29″	

TABLE IV. Results reduced to bars 1″×1″. *Distance between the supports* 2′ 3″.

	Breaking weight (*b*)	Ultimate deflection (*d*)	Power of resisting impact. (*b*×*d*)	Rates of strength Bar F 2 =1000
Experiment VI. Bar F 1 without notches	867	0·315	273	1000 : 876
Do. VII. „ F 2 „ „	989	0·38	376	1000 : 1000
Do. VIII. „ G 1 with one notch.	760	0·331	231	1000 : 768
Do. IX. „ G 2 „ „	899	0·41	368	1000 : 908
Do. X. „ H 1 with two notches	746	0·286	213	1000 : 754
Do. XI. „ H 2 „ „	703	0·29	203	1000 : 810
Mean................	829	0·335	280	1000 : 838

I have been unable to ascertain the precise composition of these bars, but assuming it to have been similar to that of the first series of bars, the greater powers of resistance shown by them would seem to indicate that the nickel employed in their preparation possessed a higher degree of purity than that used for the first series. Much, however, depends on the quality of the cast iron with which the nickel is mixed. The results derived from the foregoing experiments are conclusive, both in regard to those made on the first and those made on the second series of bars. Further experiments may, however, lead to different results; but judging from what has already been done, I am inclined to believe that chemical combinations of a different nature are required, and probably a totally different process of manufacture will have to be adopted before a sufficiently strong and satisfactory compound can be obtained.

In attempting to ascertain the effect of a mixture of nickel with cast iron, the principal object was to determine to what extent the compound gave positive or negative results. It is well known that meteoric iron is peculiarly ductile, and it was assumed that nickel, added to cast iron in such proportion as to produce a compound similar to meteoric iron, would impart to it increased ductility. The foregoing experiments lead, however, to the conclusion that an admixture of nickel produces an exactly opposite effect, and it now remains to be determined by a more extended series of experiments, whether by mixing nickel with malleable iron in the same relative proportion more satisfactory results would be obtained. In prosecuting these experiments it would be interesting to know the extent to which these metals are capable of combining chemically, and how closely such combinations would approximate to meteoric iron.

Besides endeavouring to obtain a metal of greater ductility, another object of equal importance was aimed at in these experiments, namely, to produce a metal of increased tenacity suitable for the casting of cannon and heavy ordnance. During the last two years innumerable experiments have been made for this purpose, with more or less success; but the ultimate result appears to be, that for the construction of heavy artillery there is no metal so well calculated to resist the explosion of gunpowder, as a perfectly homogeneous mass of *the best and purest cast iron,* when freed from sulphur and phosphorus.