

XIV.—*On the Composition of some Varieties of Foreign Iron.*

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THERE are few subjects of practical importance that have, during the last twelve months, attracted general attention in this country to the same extent as the question of the manufacture of iron ordnance. While numerous plans have been proposed, discussed, and tried for constructing cannon, either of wrought-iron, steel, or mechanical combinations of iron-material of different kinds, which shall be capable of throwing larger and heavier projectiles than those hitherto used, the question at issue has gradually become one of more general interest, involving considerations intimately connected with the metallurgy of iron, in consequence of the conclusions deduced from the experience in the late war, that the conditions necessary for obtaining a durable and uniform material for iron guns are as yet far from being fully determined.

The American Government has lately published a collection of reports, containing some interesting and important observations connected with the manufacture of iron ordnance, though it does not appear that the researches carried on in that country, or the experience gained by the directors of gun foundries belonging to various continental states, have as yet effected much more than the provision of a number of data relating to the nature and quality of iron employed, the different methods of treating the metal and of casting the gun, and the effects of mechanical tests and of the explosive force of powder upon iron ordnance. There is little doubt that the accumulation of such data, and extensive experiments suggested by their comparison, will ultimately lead to the establishment of the conditions necessary for insuring to iron ordnance uniformity and durability.

The collection in this country of such data as those referred to has hitherto been a matter of great difficulty, from the circumstances that iron ordnance were obtained by Government from various private sources; that no special conditions have been observed in the selection or treatment of metal for ordnance; that no records of the material employed by the different manufacturers have been preserved, and that no system of tests, physical or chemical, has been applied to the metal composing the guns, beyond the regulation proof to which ordnance were submitted before their acceptance from manufacturers. It is obvious also, from these

circumstances, that no uniformity in the iron guns used in this country could be expected.

Now that Government has determined to take the manufacture of iron ordnance into its own hands, the most serious obstacles to the perfection of these important arms in England are set aside, and the introduction of a complete system of testing and of record, together with the results of a very extensive series of experiments, on a sufficient scale, which have already been commenced, will, it is hoped, furnish important contributions to our knowledge of the constitution and mode of treatment of iron, best adapted for the manufacture of ordnance.

In carrying out the system of experiment determined upon by Government, attention has been directed, in the first place, to iron reduced from its ores by charcoal, this being the material employed exclusively, in some continental States, and to a very great extent in others, in the manufacture of iron ordnance. Much stress is laid, by many authorities on the continent, upon the greater fitness, for this purpose, of that description of iron than of the best hot-blast, or even of cold-blast iron, smelted with coal or coke. It appeared, therefore, naturally the first step, in comparative experiments with various materials, to ascertain the nature of the iron composing the most durable guns manufactured in those countries, and to determine, by comparative experiments here, whether guns manufactured from charcoal-iron exhibit great superiority over those made *according to the same system* of iron reduced from its ores by mineral fuel. Various specimens of foreign charcoal-pig-iron, and cannon of that metal made in France, Belgium, and Sweden, have been collected for comparative examination, and considerable quantities of charcoal-iron, procured from Nova Scotia, Sweden, and America, have been purchased, for experimental purposes. The results obtained, up to the present time, are principally those furnished by the analysis of several of these specimens; and I venture to submit these to the Chemical Society, as they exhibit some points of interest, and may also serve, to others engaged in similar inquiries, as additional means, to those already existing, of comparing the constitution of the varieties of charcoal-iron with that of other descriptions of iron.

It is unnecessary, in the present instance, to enter into analytical details; but, as various methods are employed, by different chemists, for determining the most important constituents in iron, it may be advisable to furnish a brief outline of those adopted in performing the subjoined analyses.

The *graphite* was determined by digesting the finely-pulverized iron with concentrated hydrochloric acid, and boiling the residue for some time with a moderately-strong solution of potassa: the graphite was collected, washed, dried, and weighed. It was afterwards placed in a capsule and heated to redness in a muffle, until the whole of the carbon was burnt off. The weight of the slight incombustible residue which was generally obtained was deducted from the weight of the graphite.

For the determination of the *total amount of carbon* the iron was reduced to an extremely fine state of division; it was then first mixed with about twice its bulk of fine sand, or powdered glass, and afterwards with a mixture of chromate of lead and chlorate of potassa. The combustion was conducted in the usual manner, a current of oxygen being frequently employed.

The proportion of *silicium* was ascertained by acting upon the finely-divided metal with concentrated hydrochloric acid, evaporating to dryness, and digesting the residue with hydrochloric acid. The insoluble portion was collected upon a filter, washed until free from iron, dried, and ignited until the whole of the carbon was burnt off. The silicic acid thus obtained was digested with solution of potassa, after its weight had been determined. If any insoluble residue was obtained its weight was deducted from that of the silicic acid.

To determine the proportion of *sulphur*, hydrochloric acid was allowed to act very slowly upon fragments of the iron, in a suitable apparatus, and the gas generated was passed through a slightly acid solution of acetate of lead. The sulphide of lead produced was collected, washed, and ultimately weighed as sulphate of lead.

The *phosphorus* was determined by digesting, in nitrohydrochloric acid, fragments of the metal, of the size of small peas, evaporating the solution to dryness, digesting the residue with hydrochloric acid, and separating the insoluble from the soluble portion. The hydrochloric solution was partly neutralised by sesquicarbonate of ammonia, and the greater part, if not the whole, of the sesquichloride of iron reduced to protochloride, by sulphite of ammonia. Solution of acetate of ammonia was then added in excess, and afterwards a small quantity of solution of sesquichloride of iron. The phosphate of iron was precipitated by boiling, collected, and dissolved in hydrochloric acid, and decomposed by sulphide of ammonium. The phosphoric acid was estimated in the usual manner, as pyrophosphate of magnesia.

In the following table is represented the percentage composition

of several specimens of iron, reduced from its ores by charcoal, as calculated from the analytical results :—

TABLE I.

Composition of Pig Iron smelted with Charcoal obtained from

	NOVA SCOTIA.			AMERICA.			FRANCE.	SILESIA.	
	Grey.	Mottled.	White.	Grey.	Mottled.	White.	Grey.	White, <i>very crys- talline.</i>	White, <i>less crys- talline.</i>
Specific gravity...	7.120	7.540	7.690	7.159	7.540	7.675	7.000	7.531	7.604
Iron.....	95.20	95.35	95.25	94.87	96.35	96.55	95.18	93.45	90.75
Combined Carbon	—	1.72	2.96	.04	1.14	2.79	—	4.94	3.62
Graphite.....	3.11	1.38	—	3.07	1.50	—	3.40	—	—
Silicium	1.11	.26	.21	1.80	.79	.32	.80	.75	.25
Sulphur .....	.01	.03	.02	trace	.01	.06	.03	trace	trace
Phosphorus .....	.13	1.30	1.53	.22	.20	.17	.45	.12	3.26
Manganese .....	.25	trace	—	trace	trace	trace	—	5.38	2.00
Copper	—	—	—	trace	trace	trace	—	.24	trace
	Traces of Titanium and Cobalt.						Traces of Arsenic and Chromium	Traces of Cobalt.	

The specimens of white iron from Silesia differ from one another in several respects, and to such an extent, as to prove that they were obtained from different ores. Both were very hard and brittle; but the ore containing the largest amount of manganese exhibited a foliated structure and brilliancy of lustre, very similar to that of refined antimony, while the other specimen, rich in phosphorus, was less brilliant and far more compact. These irons were proposed for admixture with dark grey iron; but it was considered that they could not be advantageously employed for this purpose.

The French iron examined was a specimen of the metal reduced by charcoal from hæmatite-ores, at the Government cannon foundry of Ruelle, and employed exclusively in admixture with charcoal-iron also reduced from similar ores in the neighbourhood, for the manufacture of ordnance. It was dark, soft, fine-grained, and uniform in texture. In its general characters it was similar to

the Swedish grey iron analysed, though exhibiting a superiority over the latter in reference to the amount of silicium it contains.

The specimens of American and Nova Scotia iron analyzed were taken as average samples from large parcels of the metal purchased by Government for experimental purposes.

The different varieties of iron from each source exhibit such differences in their composition as are generally observed in irons reduced from the same ore under modified conditions. Both the Nova Scotia and American irons are of excellent quality, and furnish the best results when submitted to physical tests. Comparative trials are about to be made of their merits as gun-metal.

The subjoined table exhibits the results of the analyses of four specimens, from guns of foreign manufacture.

TABLE II.
Composition of Iron Gun Metal from

	BELGIUM.	FRANCE.	SWEDEN.	RUSSIA.
Specific gravity	7.250	7.250	7.050	7.135
Iron	95.61	96.02	95.87	94.36
Combined Carbon .....	.78	1.03	.18	.47
Graphite	2.12	1.87	2.62	2.83
Silicium .....	.99	.35	1.19	1.10
Sulphur .....	.06	.03	.08	.02
Phosphorus .....	.29	.45	.11	.37
Manganese .....	.15	.25	trace	.85
Titanium	traces	traces	trace	trace
	Traces of Chromium, Arsenic, Zinc, and Copper.	Traces of Chromium and Tin.	Traces of Chromium.	Traces of Tin.

The Swedish metal examined has great resemblance to that composing the Russian gun which was one of those lately captured and selected for experiment. A severe proof to which this gun was submitted showed that the metal composing it was of excellent quality.

The Swedish metal was of a uniform light grey colour, while the Russian gun exhibited a slightly mottled appearance. Both contained the graphite in a finely divided state. It is worthy of remark, that the strength and durability of Swedish iron guns is found to be variable; which circumstance is ascribed to the very

general practice of casting the guns directly from the blast furnace, instead of first submitting the metal to treatment in reverberatory furnaces.

The specimen of French gun-metal was obtained from the cannon foundry at Ruelle. It resembled, in a remarkable manner, several specimens of iron gun-metal obtained from the cannon foundry at Liège, of which the composition of an average sample is also given in the above table. Both kinds were mottled iron of very uniform character, exhibiting a short and regular fracture, and a fine and compact structure. Their specific gravities are identical, and the differences exhibited in their composition are but slight. For the preparation of the French gun-metal, a mixture of various descriptions of charcoal pig-iron, obtained at Ruelle, is made with grey pig-iron, from other similar iron works in the neighbourhood (*e.g.* from *La Chapelle* and *Etouars*) with old French cannon, and with the "dead-heads" from former castings. By a protracted treatment in reverberatory furnaces, these metals undergo thorough mixture, and purification at the same time, and are converted into the uniform mottled metal above referred to. The fuel used for the remelting and mixing is Newcastle coal.

At the Belgian Government cannon foundry a certain proportion of hot-blast iron, smelted with coke, is employed in admixture with old cannon, "dead heads," and charcoal pig-iron, obtained from various smelting works, more particularly in the neighbourhood of Charleroi. The fuel used for the remelting is a semi-anthracite coal, from Belle Vue, in the neighbourhood of Liège, and has the following percentage composition:—

Carbon	85·56
Hydrogen	4·20
Oxygen	2·40
Nitrogen	1·92
Sulphur	1·00
Ash	4·92

The percentage of phosphoric acid in the ash is 1·60.

The same care is taken to ensure the production of a metal of uniform structure, as at Ruelle; and the excellent results obtained by the proof of the guns, and by the mechanical tests to which the metal is submitted, bear very strong evidence in favour of the superiority of iron of the particular constitution and structure produced in Belgium and France, for the manufacture of guns, over other kinds of iron, even equal to it in chemical quality.

Unquestionably the repeated exposure of grey iron to a moderately oxidising action, in the reverberatory furnace, has the effect of improving its quality, and of removing one of the impurities most objectionable in iron which is to possess tenacity and elasticity, namely, silicium. In experiments lately made, in connection with some patent processes for improving the quality of iron, it was found that the oxidising action of air upon highly-heated iron had the effect of removing the silicium entirely, before the amount of carbon existing in the metal was diminished in any sensible degree. The close-grained and very uniform structure of the iron produced by the mixing and remelting processes, on the continent, and the very finely divided condition in which the graphite exists in the iron, are elements affecting the durability of the gun-metal, of equal importance to the purity of iron. Some pieces of iron ordnance which have either burst upon proof, or after having been but a short time in use, and the metal composing which was of good quality and even of an unusually pure description, evidently owed their incapability to resist the force of gunpowder to the comparatively loose structure of the metal, and to the existence of the graphite in large scales. There are, moreover, various points to be taken into consideration, in connection with the *method of casting guns*, which cannot be entered into here; but which, doubtless, greatly influence their physical structure and, consequently, their durability.

It would be premature to attempt a comparison between the merits of charcoal-iron and those of the better qualities of British cold-blast iron, as materials for ordnance, from results of analysis alone; but thus much is certain, that iron smelted with mineral fuel may be obtained in abundance in this country, which contains not more phosphorus or sulphur than are found in average specimens of charcoal-iron, and that abundant proofs already exist of the ease with which silicium may be removed from pig-iron, by judicious treatment. It may, therefore, be confidently expected that future experiments on the casting of ordnance, with various kinds of iron, will prove that we are not dependent upon a supply of charcoal-iron, for the production of durable guns.

As an appendix to this communication, I beg to lay before the Society the results of analysis of a specimen of the cast steel manufactured by Krupp, of Essen, of which such beautiful specimens were exhibited at the Paris Exposition of 1855.

This cast-steel was proposed, by M. Krupp, as a material for ordnance, as far back as 1847, and the first small gun (a 3 pr.)

cast of it was submitted to very severe tests, in Berlin, in 1849, and finally proved to bursting. A 12-pr. gun, of the same material, was afterwards sent for trial to this country (early in 1855), after having likewise withstood very severe tests. At about the same time, a cylinder of the cast steel was sent from Essen, and bored by Messrs. Walker, of the Gospel Oak Works, to the calibre of an 8-inch gun. Its breech was fitted with a cast-iron case, or jacket, the thickness of which was 10 inches at the breech, and 8·5 in front of the trunnions. The weight of the gun complete was 8 tons 5 cwt. The case was in contact with the steel barrel only at its two extremities, at the breech and the middle of the barrel; at the latter place a wrought-iron wedge-ring was fitted into the barrel, and fixed to the jacket by screws. This gun was proved at Woolwich, but burst the first time it was fired. The probable cause of this unexpected result has been a subject of some public discussion in Germany, but there is little doubt that it was due to the injudicious form of projectile (weighing 259 lbs.) which the parties who proposed to Government the experiments with cast steel, and provided the gun for trial, insisted upon employing for the proof.

The gun was broken into ten large pieces and a number of small fragments. The various fractures of the cast steel did not exhibit any imperfections, to which the bursting of the gun could have been ascribed. The metal was very uniform, compact, and hard. A fragment was selected for analysis, and furnished the following results :—

One hundred parts contained—

Iron	98·05
Combined carbon . . .	1·18
Silicium	0·33
Phosphorus	0·02
Manganese	<i>trace</i>
Cobalt and Nickel . . .	0·12
Copper	0·30

No sulphur was detected.

The specific gravity of the specimen analysed was found to be 7·836.