THE IRON AND STEEL INSTITUTE

THE Iron and Steel Institute held its meeting on the 12th, 13th, and 14th inst., under the presidency of Dr. J. Percy, F.R.S., in the Theatre of the Institution of Civil Engineers.

The President made some introductory remarks having reference to the papers about to be read. He had strong hopes that, from a scientific point of view, great results were likely to flow from investigation of the microscopic structure of iron and steel, as it was only by physico-chemical investigation that our present ignorance of the causes of many phenomena relating to metal would be lessened or dispelled. He was peculiarly glad to read Mr. Turner's paper, as he had had the honour, when first addressing the Institute, of suggesting the solution of specific problems relating to iron and steel which had been ably attempted by the author; he should be glad to see medals or rewards conferred on those who solved problems emanating from the Institute. He made special reference to Mr. C. P. Clarke's paper, which we hope to print *in extenso*. He had great pleasure in drawing attention to Sir Henry Bessemer's gift to the Institute of a series of specimens illustrative of the process universally known by his name, which he exhibited at South Kensington some time ago. The President very shortly referred to what Sir Henry had done for metallurgy, and called upon the members to join in cordially thanking him for his gift to the Institute, which was done with acclamation.

With regard to the prevailing depression in trade, he thought over-production was the main cause of the evil in question. Considering the enormous power the iron and steel trades, for instance, possessed for production, it was not surprising that over-production should take place. Besides, what had taken place in our own country had also occurred to a greater or less extent in Germany, Belgium, France, Austria, Russia, and especially the United States of America.

British workmen had a special enemy to contend against in the fierce competition from abroad, where men labour for less wages and work longer hours. He hoped that the problem would be solved, not by our countrymen having to be paid less for their labour, but by the labourers in foreign countries rising to our level, when our trades would have less to fear from foreign competition.

Passing from the over-production of iron and steel, the President referred to the fact that the surface of the earth was limited, whilst the human race was constantly increasing, and as the world could only sustain a certain population, so portions of it could do no more; he was of opinion that what was really at the bottom of the troubles of Ireland was the sentiment of Irishmen trying to live where they could not gain their livelihoods, when there were millions of acres in our colonies which they could cultivate and be happy upon. Shortly referring to the Colonial and Indian Exhibition, the speaker concluded, a vote of thanks for his address being moved by Sir Isaac Lowthian Bell and seconded by Sir Bernhard Samuelson.

The Bessemer Medal for the year was awarded to Mr. Edward Williams, who was unfortunately prevented by ill-health from coming to the meeting to receive it.

There was a very large number of papers on the agenda, some of which had to be deferred. Amongst the papers read and discussed some were important not only technically but scientifically. Mr. P. W. Flower's paper on the origin and progress of the manufacture of tin plates is hardly of this character, but it is interesting both from an archæological and industrial point of view. Aristotle, Pliny, the Phœnicians, Herodotus, and Diodorus Siculus have all made reference to this manufacture. In more modern days we find it flourishing in Bohemia in 1620, from which country Yarranton introduced it into England about 1665, thus fortunately succeeding in benefiting the iron trade of Wales and the tin trade of Cornwall, which were both much depressed. Later on, the use of coal instead of charcoal, of vitriol for pickling-purposes in place of barley-meal, of Siemens's soft steel for charcoal iron, of Bessemer steel in place of puddled bar, have all had their influence on this industry. Ninety-six works, with 320 mills in all, work up about half a million tons of British steel and iron annually into tin plates. The production last year was over 7,000,000 boxes, of which probably 3,000,000 were used in the manufacture of 875,000,000 of 1 lb. canisters. "By means of these canisters Europe receives largely of beef from the Western prairies, salmon (in shiploads) from Oregon, mutton from the plains of Australia, fruits of all sorts from California, lobsters from Boston and Nova Scotia, oysters and peaches from Baltimore, sardines and green peas from France, pine-apples from Mauritius, apricots from Lisbon, milk from Switzerland, jams from Tasmania, and many other products of foreign soil, which complete the list of what the French have called *conserves alimentaires*."

Mr. Hamilton Smith, jun., in his paper on wrought-iron conduit pipes, refers to the method of hydraulic mining introduced in California in 1852. It may roughly be defined as the discharge of jets of water, actuated by gravity with a considerable head, against a bank of auriferous gravel, the water acting first as an excavator, and afterwards as a carrier of the washed material. The supply of water for these jets was at first conducted through hose made of heavy cotton duck cloth, which was strengthened by outer nettings of cordage when the pressure was large. In 1853 an ingenious miner laid in his main a line of pipe consisting of joints of ordinary stove-pipe, made of very thin sheet-iron lightly fastened together with cold rivets; the joints being united stove-pipe fashion. This pipe answered admirably, and in a short time all the hydraulic gravel mines in California obtained the pressure for their water-jets by means of thin sheet-iron pipes. As a protection against rust, each joint is immersed for several minutes in a bath of boiling asphalte and coal-tar; a little rosin is added when a glassy surface is desired, and sometimes a little fish-oil. After successful practice in the mines had demonstrated the advantages and capabilities of wrought-iron pipes, they were used for permanent conduits both for conducting water to mining districts across deep mountain gorges, and also for the supply of cities. San Francisco, a place of some 300,000 inhabitants, receives its water through two lines of such pipes, and a third pipe, many miles in length, and of large diameter, is now being laid for an additional supply.

"On a Neutral Lining for Metallurgical Purposes" was the title of a paper in which M. Ferd. Gautier, after describing various linings of an acid, basic, reducing, and oxidising character, refers to one in which chrome iron is the main constituent. From a physical point of view chrome ore is essentially refractory; heated in lumps it does not crumble to pieces, however high the temperature. In general metallurgy, where no alkalies in notable quantities are present, chrome iron is a refractory material of a specially neutral character, since neither acids nor bases act upon it. The chrome iron is employed shaped in pieces, and also as a mortar in combination with lime. The use of this material in the basic open-hearth process has been kept secret for some time; it was exhibited last year at the International Inventions Exhibition.

The President's paper on steel wire of high tenacity referred to experiments on the tensile strength and chemical composition of wires of various thickness. The mechanical tests were made at the request of the author by Col. Maitland, R.A., and the analyses by Sir Frederick Abel. The wire was of a very pure character, there being a percentage of total carbon 0·828, manganese 0·587, silicon 0·143, sulphur 0·009, copper 0·030, without a trace of phosphorus. The tensile strengths of the wires increased as their thickness diminished, as shown by the following table:—

Diameter in fractions of an inch	Tensile strength in tons per sq. inch
0·093	154
0·132	115
0·159	100
0·191	90

The difficulty in accounting for the increase of strength with diminution of diameter in wire-drawing is the circumstance that the density of the material diminishes during this process.

Mr. T. Blair's paper on certain necessary products of blast-furnaces, and Mr. Bauerman's note on a rare blast-furnace slag of the composition of gehlenite, were discussed together.

The paper by Mr. John Head on blow-holes in open-hearth steel brought about a very animated discussion. The blow-holes in steel, the author explained, are due to the contraction of the metal on cooling, or to the presence of imprisoned gases in its mass. Those of the first kind are removed by welding, when the steel is subjected to pressure. Those of the second kind the author maintains to be similar to what is technically known as "seedy boil" in glass, and may be removed in the manufacture of steel by not allowing the flame to touch the fused metal, just in the same way as they have been got rid of in the manufacture of glass by the use of the radiating furnace. It was suggested, in explanation of certain mysterious failures which had occurred in steel, the possibility that in these cases the gaseous blow-holes in an ingot may have sorted or arranged themselves in a series, thus forming a line of weakness in the plate or bar, which has failed along that line when subjected to a strain much below that which test-pieces from the same plate or bar would withstand. In conclusion the author had no doubt "that, by manufacturing open-hearth steel free from gaseous blow-holes, the metal produced would be much stronger and more reliable than that made by contact of flame, and the result would be a greater confidence in its use." In the discussion of this paper a unanimous verdict was given in favour of steel alike by representatives of the Admiralty, the Board of Trade, and Lloyd's Registry, who are the official judges of the metal, and by shipbuilders and boiler-makers who have found the material more trustworthy than the best iron. As regards the manufacturers, one acknowledged to the fact of there being a large difference in the total carbon, according as a sample was taken from one end or another of a large ingot, whilst another speaker had found the metal to be more regular if made in a radiation than a contact of flame furnace. As the author stated in his reply, the users were evidently even better satisfied with the material supplied them than the makers, which is certainly a favourable sign.

Mr. F. W. Webb's paper on the endurance of steel rails added further testimony to what had already been said in favour of steel. In 1876 the London and North-Western Railway put down 31,391 tons of iron and steel rails together, twelve months after which iron rails entirely disappeared, whilst the estimated requirements for this year are only 11,600 tons. The small quantity of rails required for renewals account in some measure for the depression in the steel-making trade. On the other hand, if steel sleepers are found to answer, and the author sees no reason why they should not, 45,000 steel sleepers having been put down on the London and North-Western line, and giving every satisfaction, orders for steel sleepers should in great measure make up for want of orders for rails.

Dr. H. C. Sorby drew attention to the application of very high powers to the study of the microscopical structure of steel, having employed a power of 650 linear which, being about ten times that used in his previous researches, opened out a new field for research. The chief facts were best seen in the case of an ingot of steel of medium temper. On fracture, comparatively large crystals were visible, radiating from the surface to the interior. When a properly-prepared microscopical section was viewed with a moderate power, it was easy to see that, after having crystallised out from fusion at a high temperature, these large crystals broke up on further cooling into much smaller ones. What was now seen with very high powers was that these smaller crystals finally split up into alternating very thin plates. Taking all the facts into consideration, it appeared as though a stable compound of iron with a small amount of carbon existed at a high temperature, which at a lower broke up into iron combined with a larger amount of carbon, and into iron free from it. If these two products had not differed so much in hardness, or if the alternating plates had been considerably thinner, or if definite plates had not been formed, such a compound structure would never have been suspected. It has probably never been specially looked for in other substances, and might exist without being visible, even with the highest and best magnifying powers. To give a good idea of the size of the plates, he would refer to what was seen in a longitudinal section of medium steel forged from an ingot 3 inches in diameter down to a bar 1 inch square. When broken, it showed a very fine grain, and when a prepared section was examined with a moderate power, this grain was seen to be due to crystals often about 1/1000 inch in diameter, which were not drawn out or distorted, as they would have been if they had existed previously to final cooling after hammering, and as they were distorted if the steel were hammered at a lower temperature. Examined with a power of 650 linear, these crystals only 1/1000 inch diameter were seen to contain something like 60 of the alternating plates, and even this extremely delicate structure showed little or no trace of distortion. Of course it was impossible to separate and analyse such thin plates, and reliance must be had on induction to furnish a knowledge of their nature. His reason for concluding that the hard plates contained combined carbon was that they were not seen in iron free from carbon; they increased in amount with increase of carbon, and were seen to the greatest perfection when there was a considerable amount in a combined state.

Mr. Thomas Turner's paper on the constituents of cast-iron is an attempt now made for the first time to systematise in some measure our knowledge of the constituents generally present in cast-iron, to estimate the mechanical value of any given specimen of which the chemical analysis is known, and conversely, when any given mechanical properties are desired, to predict the most suitable composition for the material. In connection with this subject two opposite opinions have been advanced by different authorities, both of which found expression at the Glasgow meeting of the Institute. On the one hand, it was suggested that probably the best mechanical properties would be obtained in a cast-iron which contained if possible nothing but carbon and iron, all other elements being regarded as impurities. On the other hand, it was said that possibly very considerable quantities of other elements might be added, even upwards of 10 per cent., without rendering the metal unfitted for the founder's use. It might be, if chemically pure iron could be obtained, that the first suggestion would be correct, and possibly if the various constituents could be added in just such proportions as to neutralise each other's ill-effects, as under such circumstances they are capable of doing, then the second suggestion might likewise prove true. As a matter of fact, pure iron cannot be manufactured, and the ill-effects of large proportions of foreign substances cannot be neutralised. A cast-iron of tolerable purity can, however, be produced, from which, by variations in the proportions of the constant constituents, a metal of desired character may be prepared. The author treats in detail of the influence of carbon, manganese, phosphorus, silicon, and sulphur, all of which are invariably present in greater or less proportion. Of these, carbon is the most important constituent, and remarkable differences are produced by variations in the proportions of combined carbon and graphite. For the more ordinary cast-iron the amount of total carbon varies from about 3 to 3·8 per cent., a lower proportion being generally due to some irregularity in the working of the blast-furnace. The relative proportion of graphitic to combined carbon can only be affected in two ways—by difference in the methods of fusion after cooling, and by variations in the proportions of other elements present. Maximum general strength, that is, considerable crushing strength combined with high tensile strength, is obtained with not less than 0·4 per cent. of combined carbon, the metal being sufficiently soft to work with the tool; with more combined carbon the metal becomes harder, its crushing strength increases while the tensile diminishes. The amount of graphitic carbon depends upon the total and combined, but, in the majority of cases, 2·6 per cent. for crushing strength, 2·8 per cent. for general strength, and 3 per cent. for strength and softness, will be found best. It is to be remembered that any required proportion of combined carbon may be obtained by altering the amount of silicon on the one hand, or of manganese and sulphur on the other, the former diminishing and the latter increasing it. As regards silicon, the experiments show that, if high crushing strength is required, it can be obtained by a low percentage of silicon; if a high tensile strength is required the silicon should be somewhat higher, while for softness, smoothness of surface, and fluidity a still higher proportion is necessary. The author is of opinion that, although phosphorus is objectionable in wrought-iron and steel, it is not so in cast-iron, the specimens which possessed the highest average quality being all moderately phosphoric irons, averaging from 0·19 to 0·72 per cent., 0·3 per cent. being a very suitable average proportion for strong iron; the amount must be proportioned according to the object the founder has in view. A small quantity of sulphur is known to produce hard white iron, owing to an increase in the amount of combined carbon, acting therefore, when in small quantity, in a manner almost exactly opposite to that of silicon. Sulphur and silicon are to a considerable extent mutually exclusive of each other in cast-iron. Thus the addition of sulphur to siliceous iron causes the separation of graphitic matter containing silicon, while the addition of silicon to an iron rich in sulphur causes the separation of graphitic matter rich in sulphur, one part of sulphur neutralising the effect of from five to ten parts of silicon. From 0·2 to 0·75 per cent. of manganese appears to exercise no injurious effect in the majority of cases, and may even be beneficial. The author considers the following to be proved, that pure cast-iron, *i.e.* iron and carbon only, and cast-iron containing excessive amounts of other constituents, would not be suitable for foundry work; that the ill-effects of one constituent can at best be only imperfectly neutralised by the addition of another constituent; that there is a suitable proportion for each constituent present in cast-iron, depending upon the character of the product desired, and upon the proportion of other elements present; and that variations in the proportion of silicon afford a reliable and inexpensive means of producing a cast-iron of any required mechanical character which is possible with the material employed.

Krupp's hot-blast pyrometer, which was shortly described, consists of an arrangement by which the hot blast is drawn with a fixed proportion of cold air into a chamber, the temperature of which, being measured with an ordinary thermometer, gives that of the hot blast by calculation.

ON DISSOCIATION TEMPERATURES, WITH SPECIAL REFERENCE TO PYROTECHNICAL QUESTIONS[1]

IN bringing the subject of dissociation before the Royal Institution of Great Britain, the author proposed to confine himself to its influence on combustion and heating, that is to say, to its effects on combustible gases and the products of combustion, and on furnace work generally. His researches had been made for the most part in connection with large gas furnaces constructed according to his new system of working with radiated heat, or what may be otherwise called free development of flame. In the first or active stage of combustion the flame passed through a large combustion chamber (all contact with its surfaces being avoided), and parted with its heat by radiation only; while in its second stage the products of combustion were brought into direct contact with the surfaces and materials to be heated, by which means the remainder of its heat was abstracted. This, in a few words, was a description of the method of heating with free development of flame. In perfecting this system of furnace, the principle of which was in many respects the reverse of that generally accepted, both as regards construction and working, he had to examine into the accuracy of certain scientific theories which could not be brought into harmony with the actual results he obtained.

Adopting the generally-accepted theory of combustion, according to which a flame consists of a chemically-excited mixture of gases, whose particles are in violent motion, either oscillating to and from each other, or rotating around one another, it followed that any solid substance brought into contact with gases, thus agitated, must necessarily have an impeding effect on their motion. Motion being the primary condition of combustion, the latter would be more or less interfered with, according to the greater or less extent of the surfaces which impede the action of the particles forming the flame; in the immediate neighbourhood of such surfaces the combustion of the gases would cease altogether, because the attractive influence of the surfaces would entirely prevent their motion; farther off, their combustion would be partial, and only at a comparatively great distance the particles of gas would be free to continue unimpeded the motion required to maintain combustion. On the other hand, the surfaces themselves must suffer from the motion of the particles of gas producing the flame, for, however small these particles might be, they produce, while in such violent motion, an amount of energy which acting constantly would in time destroy the surfaces opposed to them, just as "continual dropping wears away stone." This circumstance fully accounted for the fact that the inner sides of furnaces, and the materials they contained were soon destroyed, not by heat, but by the mechanical, and perhaps also by the chemical, action of the flame. It would seem strange that the heating power of a large volume of flame should be so much interfered with by the contact of its outer parts only with the inner sides of a large furnace chamber, if there was not another cause besides imperfect combustion to reduce the heating effect of a flame which touched the surfaces to be heated. A flame when in a state of combustion radiated heat not only from its outer surface, but also from its interior by allowing the heat to radiate through its mass. In this manner every particle of flame sent its rays in all directions, but if the flame itself touched anywhere combustion ceased there, free carbon was liberated and produced smoke which enveloped that part and prevented the rays of heat of the other portions of the flame from reaching it.

The author had avoided for various reasons referring to the subject of dissociation until recently, although it had been brought forward by several writers, and used as an argument against his new system of furnace; as according to these writers it would appear to be impossible to produce such exceedingly high temperatures as he claimed to reach. He had long held the opinion that appearances of dissociation not being observable in furnaces heated by radiation, but occurring in furnaces in which the flame was allowed to come into contact with surfaces, must be due to the action on the flame of those surfaces at high temperature. He was led to this conclusion partly from his own observations, and partly from descriptions of dissociation observed by others, amongst whom was his brother the late Sir William Siemens, who described a case of dissociation (see lecture delivered March 3, 1879, at the Royal United Service Institution, entitled "On the Production of Steel, and its Application to Military Purposes") which occurred in a regenerative gas furnace constructed according to their old views of combustion and heating. *The conclusion at which he had arrived was, that solid surfaces, besides obstructing active combustion, must also at high temperatures have a dissociating influence on the products of combustion.*

In order to obtain information on this subject he examined the laws and theory of dissociation, and endeavoured to bring the various results obtained by scientific authorities into agreement with one another, and with his own experience, but failed entirely in doing so. The temperatures of dissociation of carbonic acid and steam, the two principal gases forming the products of combustion when ordinary fuel was used, vary very much according to these observers, and the results he had obtained in practice were different from most of them. He hoped to prove that the temperature at which dissociation sets in is, in most cases, much higher than generally admitted; and that the authorities he was about to refer to had omitted in almost all the experiments they had made to take into proper consideration one element which was liable to alter materially the results obtained by them. *This element was the apparatus used for those experiments as regards its surface, form, and material.*

In considering the question of dissociation, he proposed to commence with Deville, who first discovered and called attention to the dissociation of gases at high temperatures. He made numerous experiments with various gases, and fixed certain temperatures at which he found that either complete or partial dissociation took place. Without going into details, he might mention that Deville required to use vessels and tubes of definite dimensions, material, and structure, in order to obtain the results stated. One experiment had to be made with a porous tube, another required the use of a vessel with rough interior surfaces, or containing some rough or smooth material. In this way Deville arrived at a great variety of results, and although he did not state that the rough surfaces, or porous tubes, or the solid material placed inside the vessels which he employed, had any particular influence on the temperature at which dissociation took place, yet it would appear that he could not obtain his results without having recourse to those means. Deville's results depended very much upon the various kinds of surfaces he used in his experiments, if they were not entirely brought about by them; these experiments, moreover, were of a very complicated nature, so he proposed to pass on to more modern authorities, whose experiments were of simpler character, and less open to objection.

The most important experiments which modified those of Deville were due to Bunsen. Bunsen observed the dissociation of steam and carbonic acid by employing small tubes filled with an explosive mixture of these gases, to which suitable pressure-gauges were attached. On igniting the gaseous mixture, explosion took place, and a high momentary pressure was produced within the tube; from the pressure developed, Bunsen calculated the temperature at which the explosion took place, and found that it varied with the mixtures employed. He records the circumstance that only about one-third of the combustible gases took part in the explosion, from which circumstance he concluded that the temperature attained was the limit at which combustion occurred. To prove this, Bunsen allowed the gases sufficient time to cool, after which a second explosion was produced, and even a third explosion when time was allowed for the gases to cool down again. Bunsen obtained much higher temperatures for his limits of dissociation than other physicists; these were for steam about 2400° C., and for carbonic acid about 3000° C. These temperatures were probably higher than

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[1] Lecture by Mr. Frederick Siemens at the Royal Institution, Friday, May 7.