XXV.—*Burnt Iron and Burnt Steel.*

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IRON which has been damaged by reheating is designated "burnt iron," by the workman, who also gives the same name to iron which has been excessively heated and exposed in the puddling furnace *after balling*. No amount of heat applied to iron in the blast-furnace or in the early stages of puddling produces burnt iron.

Burnt iron is brittle, its fracture is short, it displays the so-called "crystalline" structure, and it has lost the fibrous structure and silky fracture of good iron.

When steel has been raised to a yellow or white heat, and then suddenly cooled, it becomes brittle, and no longer capable of tempering, is worthless for the ordinary uses of steel until again raised to a welding heat, rolled or hammered, and allowed to cool gradually. Burnt steel has a coarse granular fracture, the facets of the granules being, for the most part, either rounded or conchoidal. The conchoidal facets serve practically as a distinguishing characteristic.

I have examined many samples of burnt iron, and find in all of them small particles of black oxide, more or less abundantly diffused throughout the mass of iron, suspended or entangled within it. I find no such particles of oxide in burnt steel, nor any other indication of internal oxidation of iron.

Important practical decisions often depend upon the determination of whether certain defects of particular samples of iron are due to burning or to other causes. I have devised a very simple means of answering this question. I take about a decigram of fresh borings or coarse filings, put them into a dry narrow test-tube, then pour upon them about three cubic centimetres of nitric acid diluted to sp. gr. 1.20. If the iron is burnt, the particles of dark oxide become separated from the metallic iron as it dissolves, and are suspended in the liquid, rendering it dark and turbid. They ultimately disappear and are thus distinguishable from particles of carbon, &c. This action is easily recognized by treating equal quantities of borings of burnt and of good iron simultaneously in the same manner, and comparing.

I find that ordinary sound wrought iron contains a small quantity of carbon, the most important function of which appears to be to prevent burning by its reducing agency. As soon as the carbon is removed, oxidation commences when the iron is heated, and this oxidation is not merely superficial, but extends throughout the mass. The higher the temperature and the greater the amount of exposure to the atmosphere while heated, the greater is the quantity of carbon required for protecting the iron. This is, I believe, the reason why all attempts to make merchantable iron by the Bessemer process have failed. The high temperature, and the violent exposure of melted metal to the air forced through it, causes oxidation of the iron to commence even in the presence of much carbon. This oxidation or burning of the iron commences in the Bessemer converter, when the proportion of carbon is brought down to about 0.25 per cent. 0.20 per cent. may be stated as the practical minimum to which it is possible to bring down the carbon of Bessemer metal without destroying malleability, but this is rarely reached. About 0.28 is the lowest ordinarily aimed at by the manufacturer.

I find that iron attains its maximum toughness, when it is otherwise pure, and its carbon is reduced to the lowest possible proportion without oxidation of the iron commencing. Thus the success of the maker of armour-plates, ship-bolts, &c., depends upon his skill in exactly touching, without passing, the point at which the oxidation of carbon ceases, and that of the iron is about to begin. By skilfully conducting his last reheating processes by means of a reducing flame, he is able to work down to the lowest possible trace of combined protecting carbon, and thus obtain the maximum of toughness and extensibility.

I find, as the result of a large number of varied experiments, that whenever steel is raised to any temperature above the lowest visible red heat, and more or less exposed to the action of atmospheric air, its carbon is oxidised with a rapidity proportionate to the temperature and degree of exposure. These experiments have extended, through a series of various conditions, from low-heat and closed annealing furnaces to the great heat and excessive exposure of the Bessemer converter. This oxidation occurs not only at the surface, but proceeds inwards. It is now well known that certain gases can pass readily through heated iron, and thus the permeation of the oxygen and exclusion of the carbonic oxide no longer presents a difficulty. I, therefore, explain the structure and properties of "burnt steel" as the result of suddenly solidifying it from the viscous condition which it attains at a welding heat, and thereby imprisoning the carbonic oxide evolved by the oxidation of the carbon. By slower cooling the carbonic oxide would have become either occluded or expelled. This explanation accords with the fact that burnt steel may be cured, as above stated, by welding up the

cavities, or "toad's eyes," as the workmen call them, which are visible on the fracture of such steel. These, according to my explanation, are the minute bubbles formed by the carbonic oxide suddenly arrested in various stages of evolution or collapse.

According to the above, the workmen's term "burnt" is not incorrectly applied in either case, the rottenness of both the iron and the steel being caused by the presence of intermingled particles of combustion-products breaking the continuity of the metal. The carbon is burnt in the case of the "burnt steel," the iron itself in the "burnt iron."