THE PRESERVATION OF IRON AND STEEL

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More than a quarter of a century ago the writer stated the opinion "that one of the most dangerous forms of construction was that in which reliance for structural strength depended upon unprotected metals."

In consequence of the partial collapse of the Charing Cross Station roof, considerable attention has been directed towards the condition of similar structures, and doubts are openly expressed as to the advisability of employing iron and steel so freely in the future as these metals have been employed in the past. It is always wise to draw general conclusions from an isolated experience, and such a course is particularly to be depreciated in the case of the Charing Cross disaster, although this concurrence will doubtless furnish useful lessons when all attendant circumstances are fully known and analyzed.

The object of the present article is to consider the effects of corrosion upon iron and steel, and to discuss methods by which the permanence of structures in which these materials are used may be extended by the application of preservative methods.

The Chemical Aspect of Corrosion.

When iron or steel is exposed to the influence of air containing water vapor and acids, the process of decay, generally described as oxidation or rusting, is commenced.

For the production of rust three substances are necessary: oxygen, aqueous vapor and an acid—and the intensity of the action depends upon the proportions of aqueous and acid vapors contained in the air. The rusting of iron takes place in two stages and as carbon dioxide is the acid most generally present, the nature of the reactions may be thus expressed:

(1) $Fe + H_2O + CO_2 = FeCO_3 + H_2$.
(2) $2FeCO_3 + 3H_2O + O = Fe_2H_6O_6 + 2CO_2$

In the first stage, water and carbon dioxide produce carbonate of iron concurrently with the liberation of hydrogen, and in the second stage the carbonate of iron combines with water and oxygen to form ferric hydrate, or rust, the carbon dioxide being set free.

The above equations do not precisely express the chemical changes taking place, because iron rust is not pure ferric hydrate, and its composition is further complicated by the occurrence of mineral acids, such as the oxides of sulphur in the atmosphere. But the explanation is sufficient to give a general idea of the process.

Thermal effect may displace that of an acid—for instance, when iron or steel is exposed to heated air, oxidation proceeds in two stages, which may be expressed as follows:

(1) $2Fe + O_3$ of air $= 2FeO + O$.
(2) $2FeO + O = Fe_2O_3$.

When superheated steam is present, a third form of oxidation is produced, that is, magnetic oxide, or forge scale Fe_3O_4, thus:

$3Fe + 4H_2O$ (super-heated steam) $= Fe_3O_4 + 8H$.

The effect of oxidation is not only destructive to the integrity of the metal, but it may also have a disruptive influence. For instance, an iron band or tie-rod encircling or penetrating masonry may disrupt or fracture such masonry by increase in the mass of the tie-rod or band as the result of the oxidation of the metal.

Examination of the expression FeH_6O_6 shows that each atom of metallic iron converted to rust is in combination with twelve atoms of hydrogen and oxygen. It is also easy to realize that the consequent increase of bulk is very great, and represents a practically irresistible force. In fact, it was the enlargement of iron ties in the same way that nearly destroyed the famous facade of St. Mark's, Venice.

To illustrate the destructive effects of the oxidation of metals, let us take the case of an unprotected wrought-iron lattice bar, 4 in. by 1 in., exposed to the air of a city, in which the aqueous proportion of the atmosphere is high, as are most of the towns in which moisture is added by the burning of hydro-carbonaceous coals. Calculating by the writer's formula given in Molesworth it will be found that the complete oxidation of the whole of the metal will require 110 years, so that in a period of fifty-five years only one-half the original material will remain. In situations where the metal is exposed to specially destructive gases, the process of decay may be still more rapid. For example, it is said that some parts of the ironwork at Charing Cross Station have already been reduced to less than one-half the original thickness, after less than forty-five years' service, and in spite of paint.

Such a statement permits one to realize the extent of the undermining influence of rusting action during a period of years in sapping the strength of metal, upon which many valuable lives may depend. If metal be subject pari passu to vibration, its entire molecular structure may be rearranged, culminating in the disappearance of the fibrous character, and in its place the establishment of the crystalline structure characteristic of cast-iron, and the corresponding reduction of tensile strength. In calculating the effect of time and work in a metallic bar exposed to the effects producing vibration, both of the influences described should always be taken into account.

Special Causes for Corrosion.

Other causes, besides the chemical action of oxygen, water and acids, may result in the corrosion of metals. For example, if iron and steel of different densities are brought into contact with each other, the less dense of the two is more liable to rust than the other.

Metals of electrical polarity opposite to those of iron and steel, either reduce or accelerate the process of rusting or oxidation. For instance, metals that are electrically positive in relation to iron and steel, preserve the latter more or less, and at their own expense. Zinc being positive in relation to iron and steel, the latter metals gain by contact with zinc, which suffers in like proportion. On the other hand, lead is negative in polarity relationship to iron and steel, and the oxidation of the latter is accelerated by contact. The same effect also applies to copper, brass, and more especially to gun-metal, which should never be brought into contact with iron or steel when exposed to an oxidizing environment, except under strict and sustained supervision.

If any one requires ocular proof of the effect of negative polarity, let him examine some old iron railings embedded in lead, and he will find striking evidence of its existence in the attenuated character of the iron near the point of contact with the lead.

The Importance of Preservatives.

It is now some fifty years since the completion of many of the metallic structures associated with the building of our railroads and although, fortunately, the margin of safety adopted by the old school of engineers was high, it behoves the supervisors of our oldest railway structures to keep a vigilant watch over the metallic structures under their care, and which were built in the early days of the Railway Era.

The importance of preserving iron and steel from the strenuous efforts of oxygen and other agents, to restore them to their native condition of iron oxide or carbonate in which they are found, has been recognized by engineers and chemists ever since the beginning of the iron and steel age. It is particularly important that these metals should be adequately protected when employed in the construction of modern habitable structures, in which the metal framework forms the weight-bearing anatomy of the structure which may be the everyday habitat of hundreds of human beings.

That most building stones and bricks, as also terracotta, are not impervious to the flow of air and the penetration of moisture is well known, thanks to the classic researches of Pettenkofer and others. Therefore, it is only to be expected that unprotected steel columns, or beams em-