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STEEL AND METHOD OF MAKING THE SAME.

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Our invention relates to a new and improved extra low carbon steel and method of making it. The novel steel described herein is primarily an effervescing steel characterized by evolution of gas in the ingot mold, as distinguished from killed steel, that is, one which is quiet in the ingot mold while molten. The effervescing steel is characterized in the solid state by containing no appreciable residuum from the ordinary killing agents such as silicon, aluminum, zirconium, titanium or manganese when used in very large quantities, in the metallic or uncombined form. Our novel steel has certain valuable properties not heretofore obtainable by ordinary commercial practice.

Our invention is based on the discovery that certain defects in or objections to extra low carbon steel as heretofore manufactured particularly red shortness, tendency to rust and low transverse ductility, have been due, not to the presence of sulphur or other impurities as has been erroneously supposed, but to the presence of oxygen in some active or uncombined form in the intergranular spaces and that by preventing the inclusion of such oxygen or, by removing it wholly or in part if it is present, the quality of the resulting steel will be enormously improved, and the defects or objections mentioned and possibly certain other defects will be eliminated.

Previous to our discoveries the presence of a thin layer of film or some substance between the several granules of steel had been observed and these layers have been thought to be iron carbide Fe_3C sometimes called cementite but its presence has not been known to have any effect on the qualities of the steel. For example, Rosenhain and Hanson in their paper on Intercrystalline fracture of mild steel in the Journal of the Iron and Steel Institute, 1920, II, 171 refer to the intergranular film as cementite, and Oberhoffer in his article in Stahl und Eisen, August 6, and 13, 1925 does not take into account at all the effect of the film being intergranular.

While we have not determined the exact nature of the intergranular substance with absolute certainty, we have reason to believe that it may be a body of the ferrous carbonyl type, that is a compound of oxygen with iron, and with possibly carbon and that it may be represented with sufficient accuracy by the formula

$$Fe[Fe(CO)_5]_n.$$

We have further determined that a chief element of this substance is oxygen which is in some active form and that it is the cause of the defects and objectionable qualities of steel mentioned above. Our observations lead us to believe, that among other effects, this oxygen bearing substance in the form of a film in the intergranular spaces between the granules of iron forms a point where a difference in potential exists and hence is the starting point for rust; also, that it separates the granules, lessening the granular ductility and cohesion and that this condition manifests itself as red shortness and low transverse ductility. Consequently our invention consists in an extra low carbon steel and the method of producing it in which the oxygen bearing film in the intergranular spaces is possibly non-existing or is reduced to a minimum, thus doing away with the objections above mentioned.

Our improved method also includes the removal of active oxygen from extra low carbon steel by the use of a suitable deoxidizing medium such as manganese, preferably in the form of one of its common ferrous alloys.

Our invention is particularly applicable to effervescing steels which have very low carbon that is, less than .05%.

The steel embodying our invention is characterized among other things by the fact that it has a low percentage of active oxygen as distinguished from oxygen in the form of insoluble oxides. In practice since it is not at the present time possible to determine with accuracy—not even with the oxygen determining apparatus devised by the United States Bureau of Standards, the proportion of active oxygen to inert oxygen, we have preferred in the following specification to refer to the total oxygen content since if the total oxygen content is low the active oxygen is likely to be so, although a high total oxygen content does not necessarily involve a high active oxygen content. The steel embodying our invention is also low in carbon and con-

tains manganese or some other equivalent element which remains as a residuum of the reaction by which the objectionable active oxygen is eliminated. The presence of this manganese, or similar deoxidizing medium, is incidental to the elimination of the active oxygen and when found in a steel which is low in carbon and has a low total oxygen content is a characteristic feature of steels embodying our invention. The steel embodying our invention is in general characterized by having carbon less than .05% oxygen less than .03% and if manganese is used as a deoxidizing agent, manganese more than .15%. There are at least three methods of determining the oxygen content of steel and these methods give widely differing results. Therefore, when we refer herein to the oxygen content we mean the oxygen content as determined by the apparatus and method devised by the United States Bureau of Standards. Furthermore, as is well known, the oxygen content is less at the outside of an effervescing ingot than at the center and consequently when such an ingot is drawn out into a bar or rolled into a sheet the oxygen content is less on the surface than at the interior of the bar or sheet as the case may be. Accordingly, in stating the oxygen content, we have taken it as the average through a sheet rolled from the middle portion of the ingot, the ends being excluded. We are aware that steels have been made in which either the carbon or the oxygen is low,—possibly less than the respective figures mentioned above. We believe ourselves the first to appreciate that steel can be made in which both elements are low and to appreciate the importance of such a steel. Such steels as have already been made have an entirely different behavior from the steels embodying our invention and we believe ourselves to be the first to recognize the importance of a low total oxygen content and consequently a low active oxygen content in extra low carbon steel.

The steel embodying our invention is also not to be confused with those killed steels which contain relatively large quantities of manganese—in general more than one per cent—since they are characterized by relatively large quantities of carbon, for example, .18 to .35% carbon, in which case the manganese is added to give the final product the necessary strength and heat treating qualities. The steel embodying our invention is also not to be confused with the so-called manganese steels in which manganese has been employed to combine with sulphur or phosphorous which have themselves been thought erroneously to be the cause of red shortness and other defects in steels. Such steels are characterized by the presence of significant quantities of manganese sulphide which differentiates them from the steels embodying our invention.

In the following specification we have used the word "steel" in its technical acceptation to mean iron and carbon combined, with or without other ingredients or alloying metals, which has been produced by complete fusion, that is, by solidification after liquefaction thus distinguishing it from wrought iron and the like which has been produced by softening but has not been subjected to complete fusion in the process of manufacture.

The steel embodying our invention has proved to be strongly rust resisting due, we believe, to the fact that there are less points at which a difference of potential exists between the intergranular film of oxygen bearing substance and the adjacent ferrite crystals or granules. Such steel is particularly adapted for use for parts of automobile bodies, for culverts, for ship plates, for boiler tubes, locomotive fire boxes and in other places where the final product is subject to rusting conditions. We also find that the range of temperatures through which red shortness appears, sometimes called the brittle range, is greatly reduced and the tendency to red shortness nearly, if not entirely, eliminated. This is a matter of the utmost importance in the manufacture of many kinds of steel, which will be appreciated when it is remembered that in the manufacture of sheets having a carbon content less than .05% it is not uncommon under some conditions to have to remelt twenty per cent of the heats because of defects due to red shortness. Furthermore, the freedom from red shortness makes it possible to manufacture seamless tubing from extra low carbon steel and furthermore therefore to produce tubing having superior qualities.

For example, an extra low carbon copper molybdenum steel has the high ductility and the corrosion resisting qualities which are desirable for the manufacture of boiler tubes, but such steel develops red shortness during fabrication to such an extent that although many attempts have been made to use it for boiler tubes it has been abandoned. Our present invention practically eliminates the red shortness and, therefore, makes it possible to employ in the manufacture of boiler tubes extra low carbon copper molybdenum steel with all of its very great advantages and with no trouble from red shortness.

While our invention relates primarily to the production of unalloyed steels it is not to be so limited, it also produces particularly beneficial results in connection with steel containing copper, molybdenum or other alloying metals. Furthermore, while in practice it is ordinarily more convenient to start with materials, as for instance, pig iron and steel scrap which themselves contain considerable quantities of carbon, that is more carbon than is required in the finished product, it will be apparent that steel containing sub-

stantially the required amount of carbon may be treated directly with the deoxidizing agent to reduce the active oxygen, or, if preferred, the carbon may be reduced as part of the process. Furthermore our novel steel may be made from wrought iron or electrolytic iron or "direct reduction" iron as a base if desired.

If it is desired to produce an unalloyed steel from pig iron and scrap steel the following procedure may be adopted. Equal parts of pig iron and scrap steel may be melted together with such a quantity of limestone as would be employed in ordinary basic open hearth practice. The heating is continued through the "boil", the boiling being characteristic of the period during which carbon is being eliminated from the bath by oxidation. This heating is continued to the point where there is no longer sufficient carbon in the bath to cause active boiling, that is, it is continued until the bath becomes quiet. During this time the bath has been thoroughly agitated to work out the suspended impurities. Thereafter ferromanganese is added, preferably in the ladle. The total oxygen content of the final product will be determined by the amount of ferromanganese employed but in practice to maintain the oxygen at less than .03 the residual manganese in the final product will be more than .15.

A typical charge for the above process is as follows: one hundred thousand pounds of steel scrap; one hundred thousand pounds of pig iron; twenty-six thousand pounds of limestone a part of which may be added to the unmelted materials and part during melting; and a thousand pounds of ferromanganese.

A typical charge for the manufacture of an alloy steel containing copper will be the same as the above with the addition of five hundred pounds of metallic copper which may be added either to the charge in the furnace or in the ladle. If molybdenum is to be used with the copper, a typical heat would be the same as the above with the addition of one hundred pounds of molybdenum in the form of a ferrous alloy or oxide or salt.

It will be understood that except as stated in the claims appended hereto we do not limit ourselves to the proportions set forth.

What we claim is:

1. A non-hot-short steel containing carbon less than .05% and oxygen less than .03%.

2. A steel containing carbon less than .05%, oxygen less than .03% and manganese more than .15%.

3. A non-hot-short and non-corrosive steel containing copper .15% to .60%, carbon less than .05% and oxygen less than .03%.

4. A non-hot-short and non-corrosive steel containing copper .15% to .60%, molybdenum .03% to .25%, carbon less than .05% and oxygen less than .03%.

5. A steel containing copper .15% to .60%, molybdenum .03% to .25%, carbon less than .05%, oxygen less than .03%, and manganese more than .15%.

6. The step in the method of making steel which consists in treating a mass of metal having less than .05% carbon with a deoxidizing agent so that the finished product will have a total oxygen content less than .03%.

7. The method of making steel which consists in adding to a mass of molten metal the carbon content of which is less than .05%, manganese, in an amount to reduce the oxygen content of the finished steel to below .03%.

8. The method of making steel which consists in oxidizing the molten metal until the remaining carbon is less than .05% and then adding manganese, in an amount to reduce the oxygen content of the finished steel to below .03%.

9. The process of making steel which consists in melting a suitable base with slag forming materials to reduce the carbon below .05% and then adding manganese in the form of one of its common ferrous alloys, to reduce the oxygen content of the finished steel below .03%.

10. The method of preventing red shortness in an extra low carbon steel, for example, one which contains less than 0.05 per cent carbon which consists in adding a deoxidizer and thereby reducing the oxygen content to less than 0.03 per cent.

11. The method of preventing red shortness in an extra low carbon steel, for example, one which contains less than 0.05 per cent carbon which consists in reducing the oxygen content to less than 0.03 per cent by the addition of manganese sufficient to leave more than 0.15 per cent manganese in the steel.

12. The method of producing an iron product which is non-hot-short at all temperatures which comprises oxidizing a suitable iron base until the carbon is less than 0.05% and then deoxidizing sufficiently to bring the oxygen content below 0.03%.

In testimony whereof we affix our signatures.

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