May 6, 1941. N. A. ZIEGLER ET AL 2,241,369

LOW TEMPERATURE IMPACT RESISTANT STEEL

Filed March 7, 1940

Fig. 1.

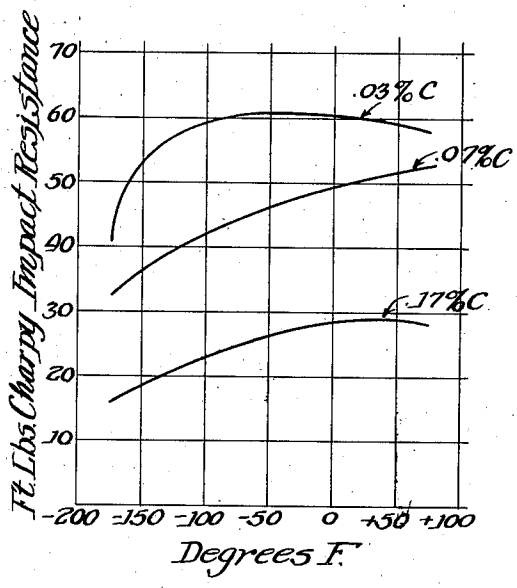
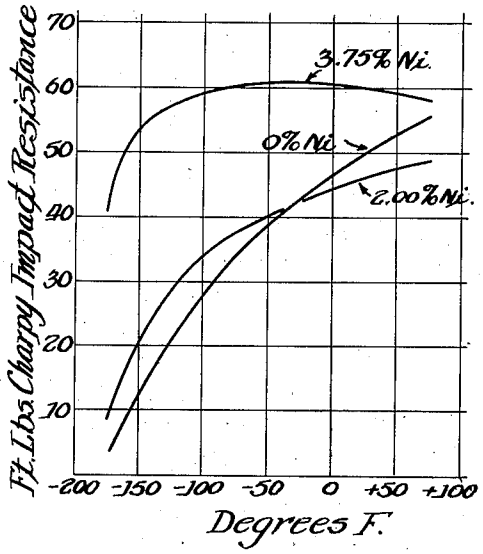


Fig. 2.



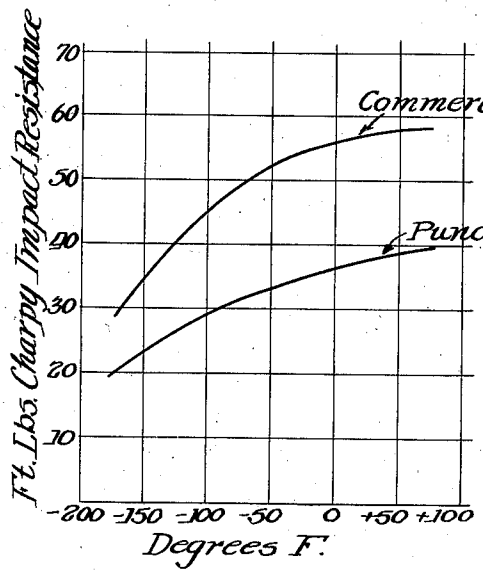


Fig. 3.

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LOW TEMPERATURE IMPACT RESISTANT STEEL

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2 Claims. (Cl. 148—31)

This invention relates to steels, and more specifically to a method of manufacturing low temperature impact resistant steels. It is well known to those skilled in the art that so-called "low alloyed steels" have a tendency to become brittle and lose their impact resistance at low temperatures as, for example, below zero temperatures. Further, the present invention appertains to low alloyed steels which have been produced in such a manner as to retain their impact resistance, and thereby become useful, at temperatures as low as minus 175 degrees Fahrenheit.

Heretofore, the tendency toward embrittlement of low alloyed steels at reduced temperatures necessitated under such conditions the utilization of either highly alloyed austenitic steels or non-ferrous alloys, each of which is considerably more expensive than low alloyed steels. We are aware, however, that others have provided low alloyed steels in which the sub-zero impact resistance has been improved, but, to our knowledge, no one has previously provided a method of producing a low temperature steel comprising in combination the composition, the method of manufacture and the heat treatment of our invention by which we obtain new and unobvious results.

It is a primary object of our invention to provide a method of manufacturing a low alloyed steel which may be cast, normalized in a novel manner and then drawn, whereby such high sub-zero impact resistances that heretofore have been unobtainable, are achieved.

Another object of our invention lies in the provision of relatively inexpensive low alloyed steels which exhibit unexpected high impact resistance values at extremely low temperatures, thereby making it unnecessary to employ expensive high alloyed austenitic steels or non-ferrous alloys for sub-zero services.

A still further object of our invention is to provide a low alloy low temperature impact resistant steel which may be cast and heat treated in a foundry wherein elaborate metal quenching apparatus is neither desirable nor economical.

The invention then consists of the composition, the method of manufacture and the heat treatment of the low alloy steel hereinafter fully described and particularly pointed out in the claims, reference being had to the accompanying drawing illustrating various embodiments of the invention, in which

Fig. 1 is a diagram which shows comparatively by graphs the effect varying amounts of carbon have upon a steel embodying our invention.

Fig. 2 is a similar diagram showing the effect of nickel added in varying percentages.

Fig. 3 is also a similar diagram showing the effect the purity of the iron has upon a steel embodying our invention.

At the outset, we wish to emphasize the necessity of the extreme care that should be exercised in the manufacturing technique and slag control in the production of a steel embodying our invention. As hereinafter set forth, the various components comprising the alloy and the preferred procedure for obtaining the desired characteristics in the alloy should be adhered to very strictly.

Referring to Fig. 1 wherein the Charpy (keyhole notch) impact resistance of steels produced in accordance with our invention and containing varying amounts of carbon are plotted against the temperature at which the tests were made, it will be noticed that an extremely low carbon content is required for improved results. It is doubtful that any gain in the impact resistance procured by a further reduction in the carbon content, which in the uppermost graph is .03%, would warrant the expenditure of the time and care necessary for obtaining the reduction thereof. Further, it will be noticed that impact resistance values of better than 40 foot-pounds were obtained at —175° F. To our knowledge nothing in the prior art of low alloy cast steels even approaches such values.

In Fig. 2 we have shown the effect of varying amounts of nickel upon our steel. In order to obtain desired results at very low temperatures, we have found that an optimum amount of nickel in the steel is approximately 3.75%, however the percentage of nickel may vary between 3.5% and 4.0% without noticeably affecting the impact resistance thereof. Steels containing still lower percentages of nickel ordinarily have reduced tensile strength and larger amounts of nickel cause the steel to be unduly expensive without any substantial contribution to its low temperature properties.

Fig. 3 illustrates graphically the difference in impact resistances at varying temperatures which have been determined in actual tests wherein commercially pure iron was used in one alloy and conventional "punchings" scrap was used in the other. The punchings which were utilized in the manufacture of the comparative alloy were of low carbon steel with care being taken to include only the punchings having relatively high purity. It will be noticed that purity of the iron aids materially in obtaining increased

impact resistance values at sub-zero temperatures and even though the chemical analyses of the two types of iron are almost identical, the physical properties are quite different. The commercially pure iron which we prefer to utilize is obtainable under the trade name "Armco Iron" and a typical analysis thereof as given in the Materials Handbook, by Brady, 1929, is:

	Percent
Iron	99.94
Carbon	0.013
Manganese	0.017
Phosphorus	0.005
Sulphur	0.025
Silicon	Trace

It has been explained that an alloy made in accordance with our invention preferably comprises relatively pure iron, about 3.75% nickel and about 0.03% carbon. We have also found that small additions of hardening elements such as, for example, molybdenum, chromium and vanadium improve the tensile strength of the alloy with little or no effect upon the low temperature impact resistance thereof. Accordingly, we have found that an alloy suitable for the practice of our invention may come within the following range of components:

	Per cent
Nickel	0 to 5
Silicon	0 to 0.7
Manganese	0 to 1.0
Carbon	0 to 0.1
Sulphur	0 to 0.04
Phosphorus	0 to 0.03
Iron	Remainder

More specifically, an alloy which proved suitable for embodiment in our invention was analyzed and contained the following components:

	Per cent
Nickel	3.61
Silicon	0.26
Manganese	0.70
Carbon	0.03
Iron	Remainder

Further, it has been found that the most satisfactory low temperature impact resistance values are obtained when the alloy composition is maintained within the following range of components:

	Per cent
Nickel	3.5 to 4.0
Silicon	0.2 to 0.4
Manganese	0.5 to 0.8
Carbon	0 to 0.07
Sulphur	0 to 0.03
Phosphorus	0 to 0.02
Iron	Remainder

In the event that increased tensile strength in the alloy is desirable, chromium up to 1.0%, molybdenum up to 0.5% or vanadium up to 0.3% may be added to the last mentioned range of components.

In more detailed reference to the relative Charpy impact resistance values at low temperatures such as —50° F., it will be noted that in Fig. 3 with commercially pure iron the impact resistance is 52 foot pounds, but when punchings are used only 34 foot pounds is obtained. Further, as shown in Fig. 2, with nickel ranges from 0 to 2% the impact resistance of approximately 40 foot pounds is obtained. However, as an indication of just how critical the nickel content is in its effect upon the increase of impact value beyond, say, 3.50%, it should be noted that with the nickel content increased to 3.75% an impact value in excess of 60 foot pounds at —50° F. is obtained. Likewise, as shown more clearly in Fig. 1, the carbon content is significant for at a temperature of —50° F. with a carbon content of .17% the impact resistance is only 27 foot pounds and with the carbon content at .07% the impact resistance value rises to 46 foot pounds, while with a carbon content of .03% the impact resistance value is in excess of 60 foot pounds.

The procedure which we prefer to follow during the manufacture of an alloy within the scope of this invention comprises melting and superheating the nickel and the commercially pure iron to about 3200 to 3400° F. in an electric induction furnace. Other types of furnaces have been found to be less desirable for the melting of the metals because of the tendency of the iron to become contaminated with an increased carbon content and other impurities. After melting and superheating the nickel and iron we prefer to introduce lime to the surface of the molten metal and to allow it to become thoroughly mixed with the melt. About ten minutes thereafter, when the lime slag is substantially impregnated with iron oxide, the slag is removed and a mixture comprising burnt lime, spar and ferro-silicon is added to the molten metal in place thereof. The function of this latter slag is to facilitate the deoxidation of the metal. The electrical power input to the furnace during the time the second slag is scavenging the metal is kept low in order to allow the slag to completely cover the metal. Thereafter the second slag is removed and further deoxidizing agents such as, for example, ferro-silicon and ferro-manganese, as well as the alloying elements (chromium, molybdenum, and vanadium), if any, are added to the charge and the entire melt is then brought to the desired pouring temperature. Additional small amounts of ferro-silicon and ferro-manganese, as well as some aluminum, all of which are commonly known as solid deoxidants, are preferably placed in the ladle before the furnace is tapped. The metal is poured at a relatively low temperature, and during the pouring of each mold, small pieces of aluminum are preferably thrown into the ladle.

The heat treatments which we have found necessary for the development of the desired low temperature impact resistance of the cast alloy steel manufactured in accordance with the foregoing preferred technique comprises four steps, namely:

1. Normalizing at about 1750° F. and cooled to room temperature.
2. Normalizing at about 1750° F. and cooled to room temperature.
3. Air quenching at about 1550° F. and cooled to room temperature.
4. Drawing at about 1200° F. and cooled to room temperature.

Relatively good impact resistance at low temperatures has previously been obtained by omitting step 2 in the above heat treatments, but we have found that "double" normalizing is essential for the attainment of the surpassingly high impact resistance values which we illustrate in the graphical drawing. Further, additional normalizing treatments at the same temperature may be of value in attaining high impact resistance values. To our knowledge, however, no one has heretofore provided a quadruple heat

treatment in combination with the composition of our alloys and manufacturing technique thereof to produce a low temperature impact resistant steel having the surpassingly high values obtainable by our invention.

Having thus described our invention it is to be understood that various changes and modifications may be made within the scope and spirit of the appended claims.

We claim:

1. A cast low alloy steel which is characterized by low temperature impact resistance comprising substantially the components nickel 3.5 to 4.0%, silicon 0.2 to 0.4%, manganese 0.5 to 0.8%, carbon from a trace to 0.07%, sulphur up to 0.03%, phosphorus up to 0.02% and commercially pure iron the remainder, the said alloy steel being produced in a highly deoxidized state and thereafter given a first normalizing treatment at about 1750° F. and cooled to room temperature, a second normalizing treatment at about 1750° F. and cooled to room temperature, an air quenching treatment at about 1550° F. and cooled to room temperature and a drawing treatment at about 1200 F. and cooled to room temperature.

2. A low alloy steel having impact resistance to temperatures as low as minus 175 degrees Fahrenheit, comprising substantially nickel between 3.5 to 4.0%, silicon up to 0.4%, manganese not exceeding 0.8%, carbon approximately 0.07%, sulphur up to 0.03%, phosphorus up to 0.02% with iron the remainder, the said alloy steel being produced in a highly deoxidized state, then subjected to a first normalizing treatment at about 1750° F. and cooled to room temperature, a second normalizing treatment at about 1750° F. and cooled to room temperature, an air quenching treatment at about 1550° F. and a drawing treatment at about 1200° F.

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