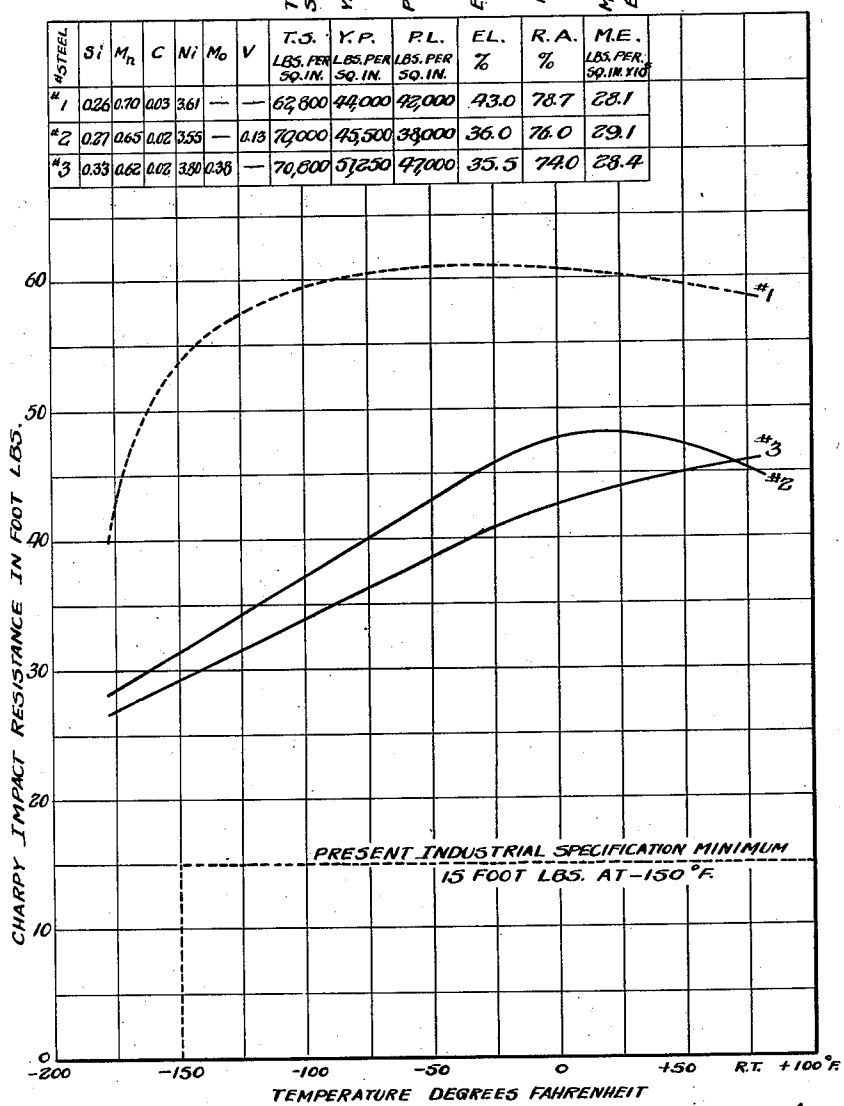
April 28, 1942. N. A. ZIEGLER ET AL 2,281,219

ALLOY STEEL

Filed Dec. 2, 1940

LOW TEMPERATURE IMPACT RESISTANT STEEL

#STEEL	Si	M_n	C	Ni	M_o	V	TENSILE STRENGTH T.S. LBS. PER SQ. IN.	YIELD POINT Y.P. LBS. PER SQ. IN.	PROPORTIONAL LIMIT P.L. LBS. PER SQ. IN.	ELONGATION EL. %	REDUCTION OF AREA R.A. %	MODULUS OF ELASTICITY M.E. LBS. PER SQ. IN. X 10^6
#1	0.26	0.70	0.03	3.61	—	—	62,800	44,000	42,000	43.0	78.7	28.1
#2	0.27	0.65	0.02	3.55	—	0.13	70,000	45,500	38,000	36.0	76.0	29.1
#3	0.33	0.62	0.02	3.80	0.36	—	70,600	51,250	47,000	35.5	74.0	28.4



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ALLOY STEEL

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Application December 2, 1940, Serial No. 368,124

3 Claims. (Cl. 148—31)

Our invention relates to a novel steel alloy having relatively high impact resistance at low temperatures. This invention is supplemental to our prior contribution to the art identified as application Serial No. 322,658, filed March 7, 1940.

In our former application our claim for invention was predicated upon a very low carbon steel containing about 3.5 to 4.0 per cent nickel which, when normalized, air quenched and then drawn was found to be capable of developing exceptionally good impact resistance properties, as for example, a Charpy impact resistance value of approximately 40 foot-pounds at such relatively low temperatures as 175° Fahrenheit below zero. It should be noted in the latter connection and in contrast to the exceedingly high physical properties above mentioned that the usual industrial specifications require as a minimum a Charpy impact resistance value of only 15 foot-pounds at 150° Fahrenheit below zero (as herein charted). Thus it is apparent that the steel referred to in our earlier application developed impact resistance values at sub-zero temperatures far in excess of minimum industrial requirements. It is thus apparent that such values could be reduced very substantially without falling below the accepted minimum established by present industrial specifications.

It should be noted, however, that the steel covered by our earlier patent application as above referred to is somewhat weak particularly in considering its tensile strength at room temperatures. Notwithstanding its very excellent low temperature impact resistance values, the tensile strength of the steel of our earlier application at room temperatures is only slightly in excess of 60,000 pounds per square inch. In the latter connection it should be understood that in the designing of engineering structures capable of resisting pipeline strains in addition to being capable of resisting internal pressures, it is generally desired by numerous specification-writing groups that the steel should possess minimum physical properties of at least 65,000 pounds per square inch tensile strength and preferably should approximate 70,000 pounds per square inch.

While being faced with the dual problem of providing a steel alloy which possesses not only acceptable physical properties at sub-zero temperatures but also at room temperatures, it was discovered that by adding small but effective amounts of such carbide-forming elements as, for example, vanadium, molybdenum, tungsten and chromium, and in all other respects following the teachings of our earlier invention, such as maintaining the balance of the analysis and also the heat treatment, the desired physical properties at room temperatures were obtainable. Thus to our original formula as set forth in our earlier patent application with its 3.5 to 4.0 per cent nickel content together with the carbon content being held within limits not to exceed .05 per cent and by subjecting such steel to the same heat treatment as set forth in detail therein, that is normalizing from 1750° Fahrenheit or double normalizing from 1750° Fahrenheit (which is optional) and then air quenching from 1550° Fahrenheit and drawing at 1200° Fahrenheit, the desirable results were obtained. The tensile strength of the resultant steel at room temperatures is at least equal to 70,000 pounds per square inch. It is appreciated that the addition of a carbide-forming element reduces somewhat the impact resistance value of the steel of our present invention over the entire temperature range, especially when compared with the original steel referred to in our co-pending application. However, as pointed out hereinafter at length, the impact value at sub-zero temperatures still remains considerably in excess of the minimum set forth in current industrial specifications.

This desirable condition is perhaps more clearly shown in the accompanying figure, in which at the lower portion of the chart the minimum Charpy impact resistance value in foot-pounds in present industrial specifications is shown in dotted lines. Attention is directed to the upper portion of the chart in which the physical properties and chemical analysis of three specimens of low temperature impact resistant steels are tabulated for purpose of comparison. In the central portion of the chart the respective Charpy impact resistance values of each of the steels above tabulated is shown.

In more detailed explanation and study of the chart, the top curve shown in dotted lines and identified as #1 at its right-hand portion represents the steel alloy described at length in our earlier invention which is #1 in the table herein and is set forth in detail in our co-pending application Serial No. 322,658. It will be noted that this steel alloy possesses the exceptional impact value of substantially 60 foot-pounds in temperatures ranging from minus 100° Fahrenheit to a plus 50° Fahrenheit but, as indicated in the upper table showing tensile strength, the latter figure is relatively low being approximately 62,800 pounds per square inch.

Directing attention now to the steel alloy curve identified as #2, and as graphically referred to

accordingly in the central portion of the chart, the impact resistance value at temperatures of minus 50° Fahrenheit is approximately 43 foot-pounds. It should be noted that the latter figure is equal to nearly three times the minimum value set forth in current industrial specifications. Yet the steel at room temperatures (see table) possesses a desirable tensile strength value of 70,000 pounds per square inch.

As a further example of the benefit gained by the addition of small but effective amounts from the group of carbide-forming elements, attention is now directed to steel #3 in which the molybdenum content is approximately .38 per cent. Here it will be noted on the chart that the Charpy impact resistance value is approximately 39 foot-pounds at a temperature of minus 50° Fahrenheit, and again it will be noted that the latter figure is considerably in excess of the present industrial specification.

It should be noted that at minus 150° Fahrenheit the #2 steel with .13 per cent vanadium possesses a Charpy impact resistance value of approximately 32 foot-pounds, while the #3 steel with a molybdenum content of .38 per cent has a Charpy impact resistance value of approximately 29 foot-pounds which is far in excess of the present industrial specification minimum of 15 foot-pounds at minus 150° Fahrenheit. Thus it is apparent that, if and when necessary, a substantial portion of the impact resistance value of the #1 steel may be sacrificed for the benefit of improving its tensile strength at room temperatures while continuing to maintain the impact resistance value substantially above the minimum requirements of current industrial specifications.

It should be apparent that while reference is made specifically to the use of vanadium, molybdenum, tungsten or chromium as the elements responsible for the improvement in tensile strength at room temperatures, the latter elements are merely selected as being illustrative of a group of other not specifically named carbide-forming elements. Further, it should be noted that where mention is made hereinafter in the claims to "cooled to room temperature" it is, of course, understood that this refers broadly, insofar as effect is concerned, to cooling below the critical temperature which is below 1100° Fahrenheit. Accordingly, our invention is capable of numerous modifications and we desire therefore to be limited only to the extent prescribed by the prior art and as set forth in 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 per cent, silicon 0.2 to 0.4 per cent, manganese 0.5 to 0.8 per cent, carbon up to .07 per cent, the usual incidental contents of sulphur and phosphorus not to exceed .05 per cent, a carbide-forming element of the character described in an effective amount not to exceed 0.5 per cent, the remainder being substantially iron, the said alloy steel being produced in a highly deoxidized state and thereafter given a first normalizing treatment at about 1750 degrees Fahrenheit and cooling to room temperature, a second normalizing treatment at about 1750 degrees Fahrenheit and cooled to room temperature, an air quenching treatment at about 1550 degrees Fahrenheit and cooled to room temperature, and a drawing treatment at about 1200 degrees Fahrenheit and cooled to room temperature.

2. A cast low alloy steel which is characterized by low temperature impact resistance, comprising substantially the components nickel 3.5 to 4.0 per cent, silicon 0.2 to 0.4 per cent, manganese 0.5 to 0.8 per cent, carbon up to .07 per cent, the usual incidental contents of sulphur and phosphorus not to exceed .05 per cent, molybdenum in an effective amount up to 0.5 per cent, with commercially pure iron the remainder, the said alloy steel being produced in a highly deoxidized state and thereafter given a normalizing treatment at about 1750 degrees Fahrenheit and cooled to room temperature, an air quenching treatment at about 1550 degrees Fahrenheit and cooled to room temperature, and a drawing treatment at about 1200 degrees Fahrenheit and cooled to room temperature.

3. A cast low alloy steel which is characterized by low temperature impact resistance, comprising substantially the components nickel 3.5 to 4.0 per cent, silicon 0.2 to 0.4 per cent, manganese 0.5 to 0.8 per cent, carbon up to .07 per cent, the usual incidental contents of sulphur and phosphorous not to exceed .05 per cent, in an effective amount of vanadium up to 0.5 per cent, with commercially pure iron the remainder, the said alloy steel being produced in a highly deoxidized state and thereafter given a normalizing treatment at about 1750 degrees Fahrenheit and cooled to room temperature, an air quenching treatment at about 1550 degrees Fahrenheit and cooled to room temperature, and a drawing treatment at about 1200 degrees Fahrenheit and cooled to room temperature.

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