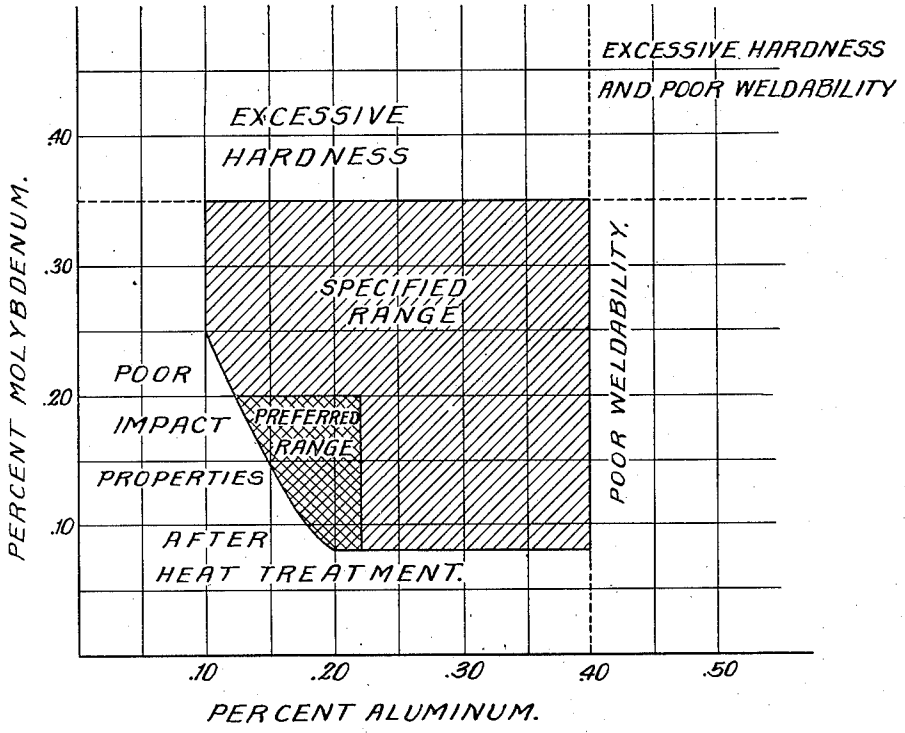
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ALLOY STEEL

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ALLOY STEEL

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The invention relates to steel and more particularly to alloy steel of the low alloy type.

A number of years ago, steels of this type were developed in order to meet a need in building relatively light-weight railway freight cars. The plain carbon steels theretofore employed in such car construction were relatively low in tensile strength and yield point and placed too much weight in the car for the strengths demanded. The steel industry met this problem by providing low alloy steels which had substantially higher tensile strengths and yield points and thus permitted a reduction in weight. Other requirements of this type of steel were that the cost be not substantially increased and that the steel be ductile, corrosion resistant and readily weldable. Such steels were intended to be used and were generally used in the "as rolled" condition, although some of them could be heat treated.

Steels of this type heretofore available thus met the needs of the industry except for one characteristic. It was noted that the notched impact properties of the steel were sufficient in the "as rolled" condition. However, the steel was frequently heat treated by the fabricator for various purposes such as to relieve stress after welding. When certain of these steels were so treated, the impact properties dropped to a low value.

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tensile strength substantially higher than those of steels of this type heretofore made and having a substantially higher impact resistance in the heat treated condition.

Another object is to provide a steel of this type, which when heat treated has a much higher yield point and higher ductility as well as a much higher impact resistance than steels of this type heretofore made.

Steels of this type, which have been on the market, frequently include copper, nickel, phosphorus and silicon in addition to carbon and manganese. Other elements are present in such steels but not of sufficient extent or of a character as to effect problems herein considered. The elements named frequently fall within the following limits:

	Per cent
Carbon	.01 to .15
Manganese	.40 to 1.00
Phosphorus	.05 to .13
Silicon	.02 to .20
Copper	.80 to 1.30
Nickel	.40 to 1.00

Steel of the foregoing character can be heat treated to greatly increase the yield point and tensile strength. To illustrate such increase, the following example of actual tests is given:

Composition					Treatment	Yield point	Tensile strength	Elong. 2"	R. A.
C	Mn	P	Cu	Ni					
						Lbs. per sq. in.	*Lbs. per sq. in.*	*Per cent*	*Per cent*
0.09	0.58	0.117	1.07	0.62	As rolled	57,320	73,480	35.8	64.2
.09	.58	.117	1.07	.62	1000° F.—4 hrs.	73,180	87,920	28.0	61.2

The general object of the invention is therefore to provide a steel of this general type which can be heat treated to provide a yield point and

The marked decrease in impact resistance resulting from such heat treatment is demonstrated by the following test results:

Composition					Treatment	Charpy impact resistance		
C	Mn	P	Cu	Ni		75° F.	0° F.	—25° F.
0.09	0.62	0.103	1.16	0.63	As rolled	46.5	35.5	31.5
.09	.62	.103	1.16	.63	1050° F.—4 hrs.	35.5	4.5	2.5

It is to be noted that the decrease in impact resistance is particularly severe in the lower temperatures in the heat treated steel having the desired high yield point and tensile strength. In fact, the impact resistance is so low that such steel should not be employed in certain fields where its other qualities would make it suitable, as in the case of tractors and road building equipment.

I have found that such other qualities can be maintained or even bettered and the impact resistance held sufficiently high by the addition of certain amounts of aluminum and molybdenum to a steel having substantially the same composition of alloying elements heretofore employed. Both the aluminum and molybdenum may be varied in quantity but the sum of the two should be not substantially less than 0.28%. Neither aluminum nor molybdenum alone will accomplish the desired result. I am aware of the fact that the so-called fine-grained steels contain from .01 to .08% aluminum. Such quantities do not attain the result herein sought. The aluminum content herein contemplated is considerably greater.

However, if the aluminum content is on the low side, it appears to be desirable to have the sum of the elements somewhat higher, while if the aluminum is high, the sum of the two may be lower but in no case substantially less than .28%. The minimum value for the aluminum content may be as low as 0.10%, of course combined with the necessary amount of molybdenum to make the sum at least as high as above stated. Thus, the aluminum content is much more than is used to produce fine grain steels and may in fact have the opposite effect. The molybdenum content must have as its minimum not substantially less than 0.08%. The exact amounts of both of the elements in any instance is usually determined by other considerations, but is confined to the amounts suggested above for each element and the sum of the two. It is not known just why the addition of these in the quantities stated has the desired effect, but I have discovered and definitely established that they do have such effect and that both must be present. The result thus must be due to the cooperative effect of the two metals.

The combined content of the two elements is preferably as above stated. However, the sum of the two may exceed that value and the steel will still have just as high impact resistance. But, if the aluminum content is raised higher than 0.40%, it will have a detrimental effect on the weldability of the steel, while raising the molybdenum content above 0.35% causes an undesirable increase in hardness.

The physical properties including the impact resistance desired could possibly be obtained by a high alloy steel, but the cost of alloying elements and the cost of the necessary heat treatment for such steel would make the cost prohibitive. The steel herein contemplated is not to be confused with high alloy steels of such character. The cost of producing the present steel may be held to a minimum by using more aluminum and less molybdenum, since molybdenum is much more expensive, the molybdenum of course being held above the minimum limit stated.

To illustrate graphically the quantities of aluminum and molybdenum contemplated by the invention, I have prepared a chart shown in the drawing. In this, the values of aluminum are plotted as abscissa and the values of molybdenum are ordinates. The larger shaded area represents the maximum range for both metals while the smaller cross-hatched area represents the preferred range.

The enhanced physical properties of the old steel obtained by heat treatment were not available for use because of the greatly reduced impact resistance resulting therefrom. The new steel retains the high impact resistance after heat treament, whether such treatment is for obtaining greater physical properties or for relieving welding stresses or for other reasons. The heat treatment herein contemplated consists generally in heating to temperatures ranging from 900° F. to 1150° F. and holding it for from one to thirty-six hours, preferably followed by slow cooling. It is to be understood, however, that the invention is not limited to heat treatment at the specific temperatures and for specific periods of time stated above nor for any particular cooling rate.

The results of two tests on a heat treated steel made in accordance with the invention are shown below:

Composition							Heat treatment	Charpy impact		
C	Mn	P	Cu	Ni	Al	Mo		75° F.	0° F.	—25° F.
0.10	0.71	0.076	1.08	0.58	0.17	0.15	1050° F.—4 hrs	53.0	36.0	33.0
.10	.71	.076	1.08	.58	.17	.15	do	57.0	47.0	44.0

When either the aluminum or molybdenum content is below that falling within the scope of the invention, the impact resistance is far below that desired as shown by the following test results:

Composition							Heat treatment	Charpy impact		
C	Mn	P	Cu	Ni	Al	Mo		75° F.	0° F.	—25° F.
0.10	0.68	0.115	1.14	0.62	0.06	0.01	1050° F.—4 hrs	35.0	2.0	2.5
.09	.68	.098	1.18	.65	.14	.05	do	46.0	4.0	2.0
.10	.63	.112	1.23	.63	.06	.10	do	30.5	3.0	2.5

The yield point and tensile strength of steels of the character herein disclosed are illustrated by the following results of tests:

Composition									Treatment	Yield point	Tensile strength	Elong. in 2"	Reduction of area
C	Mn	P	S	Si	Cu	Ni	Al	Mo					
										Lbs. per sq. in.	*Lbs. per sq. in.*	*Per cent*	*Per cent*
0.10	0.69	0.092	0.027	0.07	1.09	0.63	0.16	0.15	As rolled	56,580	75,840	45.0	56.3
.10	.69	.092	.027	.07	1.09	.63	.16	.15	do	57,250	76,450	46.5	62.0
.10	.69	.092	.027	.07	1.09	.63	.16	.15	1000° F.—4 hrs.	70,610	87,200	35.0	56.1
.10	.69	.092	.027	.07	1.09	.63	.16	.15	do	71,060	88,400	33.0	57.7

From these, it will be apparent that I have provided a novel low alloy steel which can be heat treated to provide a high yield point and tensile strength and still maintain a high impact resistance at all temperatures. This characteristic qualifies the steel for much more extensive use than was possible with the old steel and particularly fits it for use in the construction of tractors and road building equipment. Not only does it accomplish this result but it makes it a better steel to use in many instances where the old steel seemed sufficient. For example, in the construction of freight cars, the substantial increase in impact resistance as well as the very high yield point and tensile strength is obviously beneficial.

I claim:

1. An alloy steel having high impact resistance for low temperatures in the "as rolled" condition as well as after a stress-relieving heat treatment, said steel containing .01% to .15% carbon, .40% to 1.00% manganese, .05% to .13% phosphorus, .02% to .20% silicon, .80% to 1.30% copper, .40% to 1.00% nickel, .10% to .22% aluminum, and .08% to .20% molybdenum, the combined value of the aluminum and molybdenum being not less than .28% the balance being substantially all iron.

2. An alloy steel having high impact resistance for low temperatures in the "as rolled" condition as well as after a stress-relieving heat treatment, said steel containing .01% to .15% carbon, .40% to 1.00% manganese, .05% to .13% phosphorus, .20% silicon maximum, .80% to 1.30% copper, .40% to 1.00% nickel, .10% to .22% aluminum, and .08% to .20% molybdenum, the combined value of the aluminum and molybdenum being not less than .28%, the aluminum being sufficient to provide a combined value near .28% when the molybdenum is at a low value, and the molybdenum being sufficient to provide a combined value somewhat higher than .28% when the aluminum is at a low value, the balance being substantially all iron.

3. An alloy steel having high impact resistance for low temperatures in the "as rolled" condition as well as after a stress-relieving heat treatment, said steel containing .01% to .15% carbon, .40% to 1.00% manganese, .05% to .13% phosphorus, .20% silicon maximum, .80% to 1.30% copper, .40% to 1.00% nickel, .10% to .40% aluminum, and .08% to .35% molybdenum, the balance being substantially all iron, the lower values of aluminum being used only with the higher values of molybdenum and vice versa, the combined value of the aluminum and molybdenum being not less than .28%.

4. An alloy steel having high impact resistance for low temperatures in the "as rolled" condition as well as after a stress-relieving heat treatment, said steel containing .01% to .15% carbon, .40% to 1.00% manganese, .13% maximum phosphorus, .20% maximum silicon, .80% to 1.30% copper, .40% to 1.00% nickel, .10% to .22% aluminum, and .08% to .20% molybdenum, the combined value of the aluminum and molybdenum being not less than .28%, the balance being substantially all iron.

5. A heat treated alloy steel containing .01% to .15% carbon, .40% to 1.00% manganese, .05% to .13% phosphorus, .02% to .20% silicon, .80% to 1.30% copper, .40% to 1.00% nickel, .10% to .22% aluminum, and .08% to .20% molybdenum, the combined value of the aluminum and molybdenum being not less than .28%, the balance being substantially all iron, the heat treatment comprising heating the steel from 900° F. to 1150° F. and holding it at such temperature for from one to thirty-six hours to increase the yield point and tensile strength without any substantial loss of impact properties at temperatures substantially below 75° F.

6. A heat treated alloy steel containing .01% to .15% carbon, .40% to 1.00% manganese, .05% to .13% phosphorus, .20% silicon maximum, .80% to 1.30% copper, .40% to 1.00% nickel, .10% to .22% aluminum, and .08% to .20% molybdenum, the combined value of the aluminum and molybdenum being not less than .28%, the aluminum being sufficient to provide a combined value near .28% when the molybdenum is at a low value, and the molybdenum being sufficient to provide a combined value somewhat higher than .28%, when the aluminum is at a low value, the balance being substantially all iron, the heat treatment comprising heating the steel from 900° F. to 1150° F. and holding it at such temperature for from one to thirty-six hours to increase the yield point and tensile strength without any substantial loss of impact properties at temperatures substantially below 75° F.

7. A heat treated alloy steel containing .01% to .15% carbon, .40% to 1.00% manganese, .05% to .13% phosphorus, .20% silicon maximum, .80% to 1.30% copper, .40% to 1.00% nickel, .10% to .40% aluminum, and .08% to .35% molybdenum, the balance being substantially all iron, the lower values of aluminum being used only with the higher values of molybdenum and vice versa, the combined value of the aluminum and molybdenum being not substantially less than .28%, the heat treatment comprising heating the steel from 900° F. to 1150° F. and holding it at such temperature for from one to thirty-six hours to increase the yield point and tensile strength without any substantial loss of impact properties at temperatures substantially below 75° F.

JAMES W. HALLEY.