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NICKEL-FREE, LOW-ALLOY, HIGH-STRENGTH STEEL

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6 Claims. (Cl. 75—126)

This invention relates to a nickel-free, low-alloy, high-strength steel characterized in the quenched and tempered condition by the combination of good-notch toughness, as evidenced by a low transition temperature, and a high yield strength along with good weldabiilty.

There is a need in mining, earth moving and similar equipment for a low-alloy, economical steel, combining high yield strength and good-notch toughness along with ready weldability in thicknesses up to 1". It is desirable that such qualities be obtained with a minimum of expensive alloying elements such as molybdenum and without the use of the critical element nickel. We have discovered that a minimum yield strength of 90,000 p. s. i. and a transition temperature below —100° F. in plates up to 1" thick can be obtained in steel in the quenched and tempered condition within the following compositional ranges:

	Percent
Carbon	.12 to .21
Manganese	.50 to 1.00
Phosphorus	max .04
Sulphur	max .04
Silicon	.10 to .75
Copper	0 to .50
Chromium	.30 to .75
Molybdenum	.15 to .45
Vanadium	.03 to .10
Titanium	.01 to .03
Boron	.0005 to .005

with the balance iron and residual impurities.

Preferably the steel should be restricted to the following compositional limits:

	Percent
Carbon	.14 to .18
Manganese	.60 to 1.00
Phosphorus	max .025
Sulphur	max .025
Silicon	.15 to .35
Chromium	.40 to .60
Molybdenum	.15 to .25
Vanadium	.03 to .07
Titanium	.015 to .02
Boron	.0015 to .003

balance iron and residual impurities along with .25 to .35% copper if maximum corrosion resistance is desired.

The following examples will illustrate the excellent properties obtainable with the steel of this invention.

A 1" thick plate with the following chemical composition, in percent, was water quenched from 1675° F. and then tempered for 1 hour at 1175° F.:

Heat No.	C	Mn	P	S	Si	Cu	Cr	Mo	V	Ti	B
1	0.19	0.63	0.031	0.034	0.17	0.30	0.46	0.21	0.06	0.03	0.0030

After the aforementioned heat treatment, the mechanical properties of material at the center of the plate thickness were as follows:

Yield Strength (0.2% Offset), p. s. i.	Tensile Strength, p. s. i.	Elongation in 2 inches, Percent	Reduction of Area, Percent	Transition Temperature,[1] ° F.
114,900	122,000	19.8	61.6	—157

[1] Keyhole-notched specimens.

It is apparent from these data that the steel of this invention possesses a high yield strength substantially in excess of 90,000 p. s. i. along with good notch toughness as evidenced by a transition temperature substantially below —100° F.

The following heat illustrates that steel within the broad compositional limits outlined above will develop the desired properties, if properly heat treated, although not to as high a degree as steel within the preferred compositional limits:

Heat No.	C	Mn	P	S	Si	Cr	Mo	V	Ti	B
2	0.12	0.67	0.022	0.022	0.23	0.37	0.14	0.03	0.02	0.0015

A ½" and a 1" thick plate of this heat were hot rolled, quenched from 1675° F., and then the ½" thick plate was tempered for 1 hour at 1175° F. and the 1" thick plate was tempered for 1 hour at 1100° F. A lower tempering temperature was used for the 1" thick plate than for the ½" thick plate because with the low alloy content, the 1" plate did not develop as much martensite at the center as did the ½" plate and with the low carbon and vanadium contents, the steel was less resistant to tempering than steels with higher carbon and vanadium contents. The mechanical properties representtaive of the centers of these two plates are as follows:

Plate Thickness, inches	Yield Strength (0.2% Offset), p. s. i.	Tensile Strength, p. s. i.	Elongation in 2", Percent	Reduction of Area, Percent	Transition Temperature, 1° F.
1	92,800	105,300	22.5	68.8	—140
½	96,300	106,900	[2] 21.5	71.5	—215

[1] Keyhole-notched specimens.
[2] Subsize (0.252" diameter) specimens were used, therefore, elongation is in 1".

Thus, these data show that even with low alloy contents, the new steel can be heat-treated to develop high strength and good notch toughness, as evidenced by transition temperatures will below any ambient temperature that might be encountered in applications such as those for which the new steel is intended.

It should be noted that there is no copper in heat No. 2, yet the steel exhibits mechanical properties similar to those of the steel of heat No. 1, which steel contained 0.30% copper. Thus, copper, which was added for its known contribution to corrosion resistance, has little or no effect on the mechanical properties of the new steel, and can be added to or omitted from the steel, depending on the degree of corrosion resistance desired.

While we have shown and described several specific embodiments of our invention, it will be understood that these embodiments are merely for the purpose of illustration and description and that various other forms may be devised within the scope of our invention, as defined in the appended claims.

We claim:

1. A low-alloy, high-strength, nickel-free steel characterized in the tempered martensitic condition in thick-

nesses up to 1" by a yield strength in excess of 90,000 p. s. i. in combination with good-notch toughness as evidenced by a transition temperature below —100° F. and good weldability, said steel containing

	Percent
Carbon	.12 to .21
Manganese	.50 to 1.00
Silicon	.10 to .75
Copper	0 to .50
Chromium	.30 to .75
Molybdenum	.15 to .45
Vanadium	.03 to .10
Titanium	.01 to .03
Boron	.0005 to .005

with the balance iron and residual amounts of other elements.

2. A low-alloy, high-strength, nickel-free steel characterized in the tempered martensitic condition in thicknesses up to 1" by a yield strength in excess of 90,000 p. s. i. in combination with good-notch toughness as evidenced by a transition temperature below —100° F. and good weldability, said steel containing

	Percent
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Titanium	.015 to .02
Boron	.0015 to .003

balance iron, residual amounts of other elements and .25 to .35% copper.

3. A low-alloy, high-strength, nickel-free steel characterized in the tempered martensitic condition in thicknesses up to 1" by a yield strength in excess of 90,000 p. s. i. in combination with good-notch toughness as evidenced by a transition temperature below —100° F. and good weldability, said steel containing

	Percent
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Vanadium	.03 to .07
Titanium	.015 to .02
Boron	.0015 to .003

balance iron and residual amounts of other elements.

4. Low-alloy, high-strength, nickel-free steel articles fabricated from plates of less than 1" thickness having a tempered martensitic microstructure characterized by a yield strength in excess of 90,000 p. s. i. in combination with good-notch toughness as evidenced by a transition temperature below —100° F. and good weldability, said steel containing

	Percent
Carbon	.12 to .21
Manganese	.50 to 1.00
Silicon	.10 to .25
Copper	0 to .50
Chromium	.30 to .75
Molybdenum	.15 to .45
Vanadium	.03 to .10
Titanium	.01 to .03
Boron	.0005 to .005

with the balance iron and residual amounts of other elements.

5. Low-alloy, high-strength, nickel-free steel articles fabricated from plates of less than 1" thickness having a tempered martensitic microstructure chaarcterized by a yield strength in excess of 90,000 p. s. i. in combination with good-notch toughness as evidenced by a transition temperature below —100° F. and good weldability, said steel containing

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Vanadium	.03 to .07
Titanium	.015 to .02
Boron	.0015 to .003

balance iron, residual amounts of other elements and .25 to .35% copper.

6. Low-alloy, high-strength, nickel-free steel articles fabricated from plates of less than 1" thickness having a tempered martensitic microstructure characterized by a yield strength in excess of 90,000 p. s. i. in combination with good-notch toughness as evidenced by a transition temperature below —100° F. and good weldability, said steel containing

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Vanadium	.03 to .07
Titanium	.015 to .02
Boron	.0015 to .003

balance iron and residual amounts of other elements.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,858,206 October 28, 1958

Joseph F. Boyce et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 38, for "representtaive" read -- representative --; lines 42 and 43, in the heading to the table, sixth column thereof, for "Temperature, 1° F." read -- Temperature, 1 °F. --; line 53, for "will" read -- well --.

Signed and sealed this 27th day of January 1959.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents