

Aug. 29, 1933.

E. C. BAIN ET AL

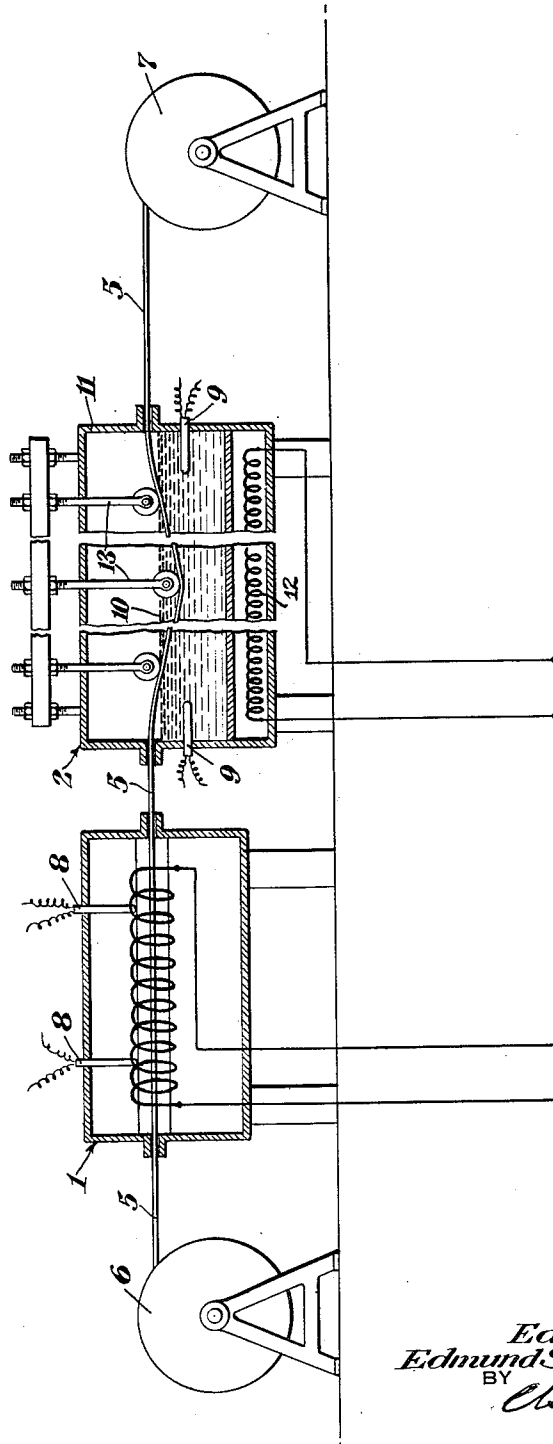
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THERMALLY HARDENING STEEL

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4 Sheets-Sheet 1

Fig. 1.



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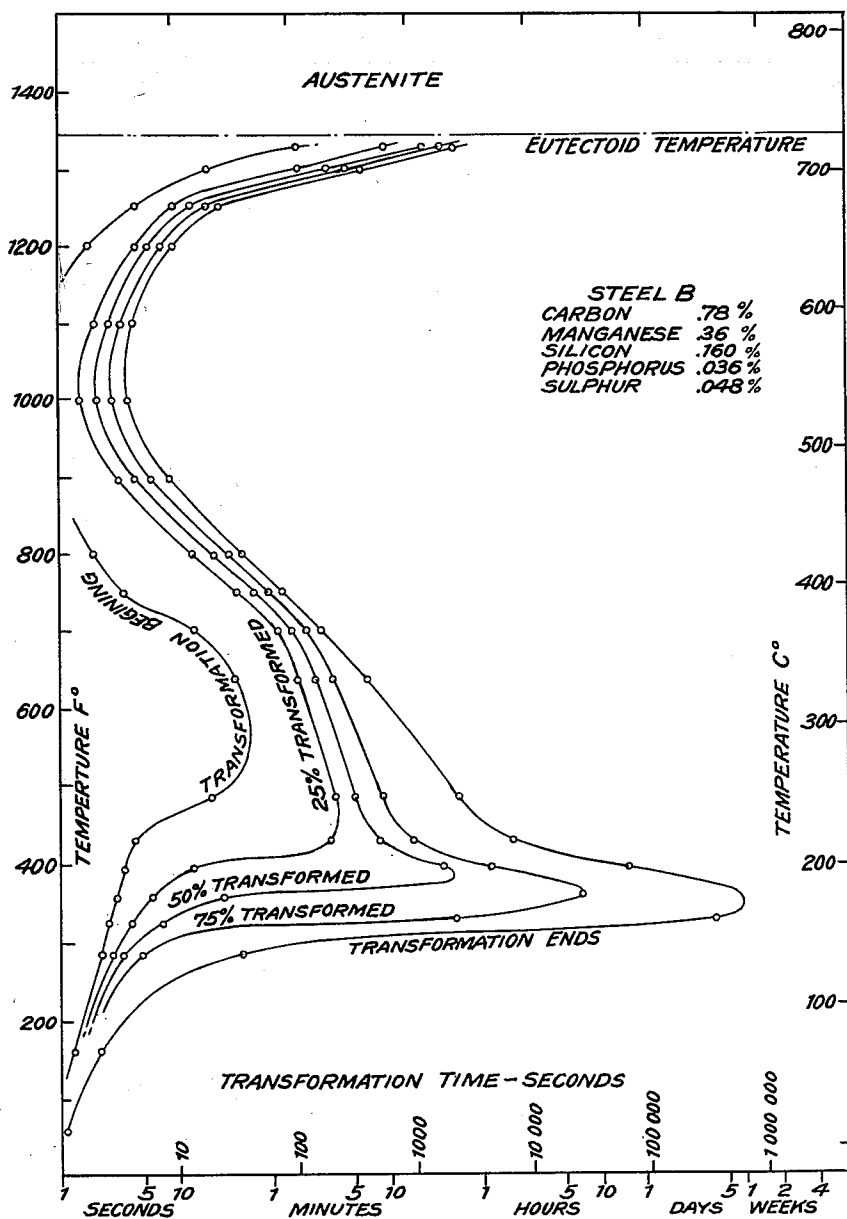
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Fig. 2.



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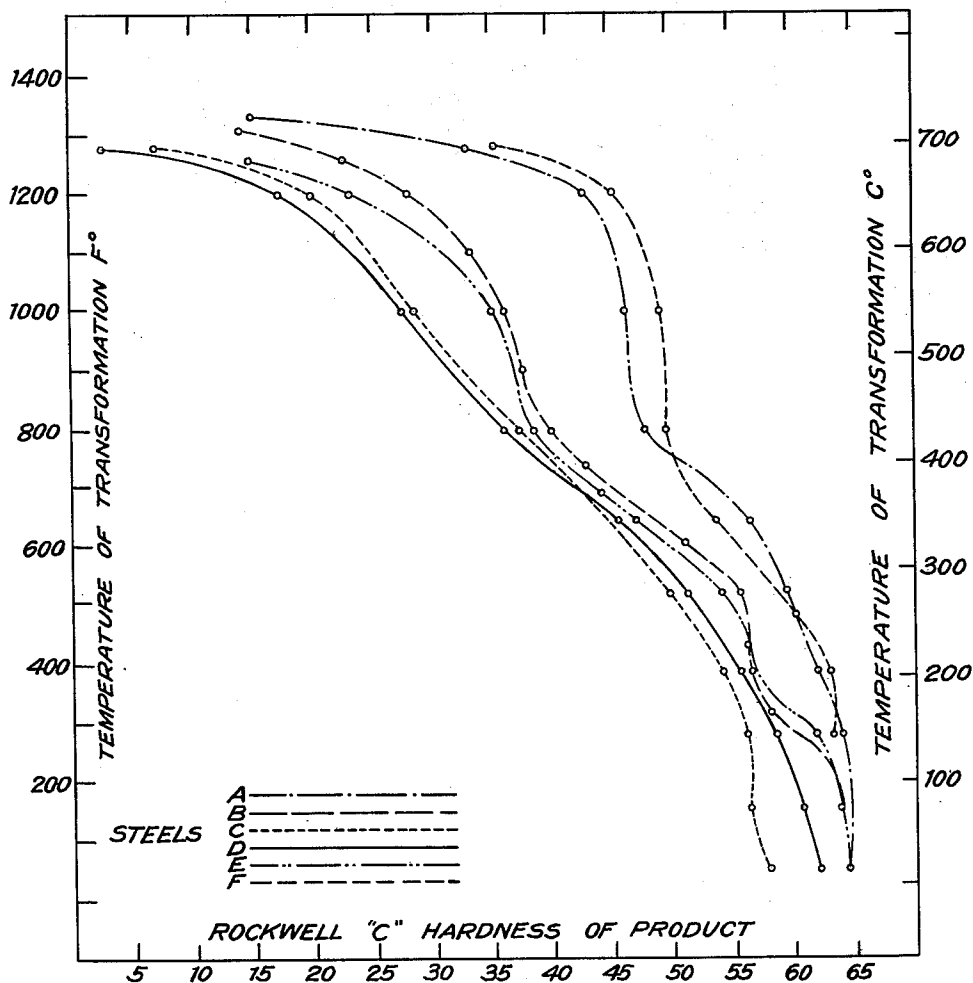
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Fig. 3.



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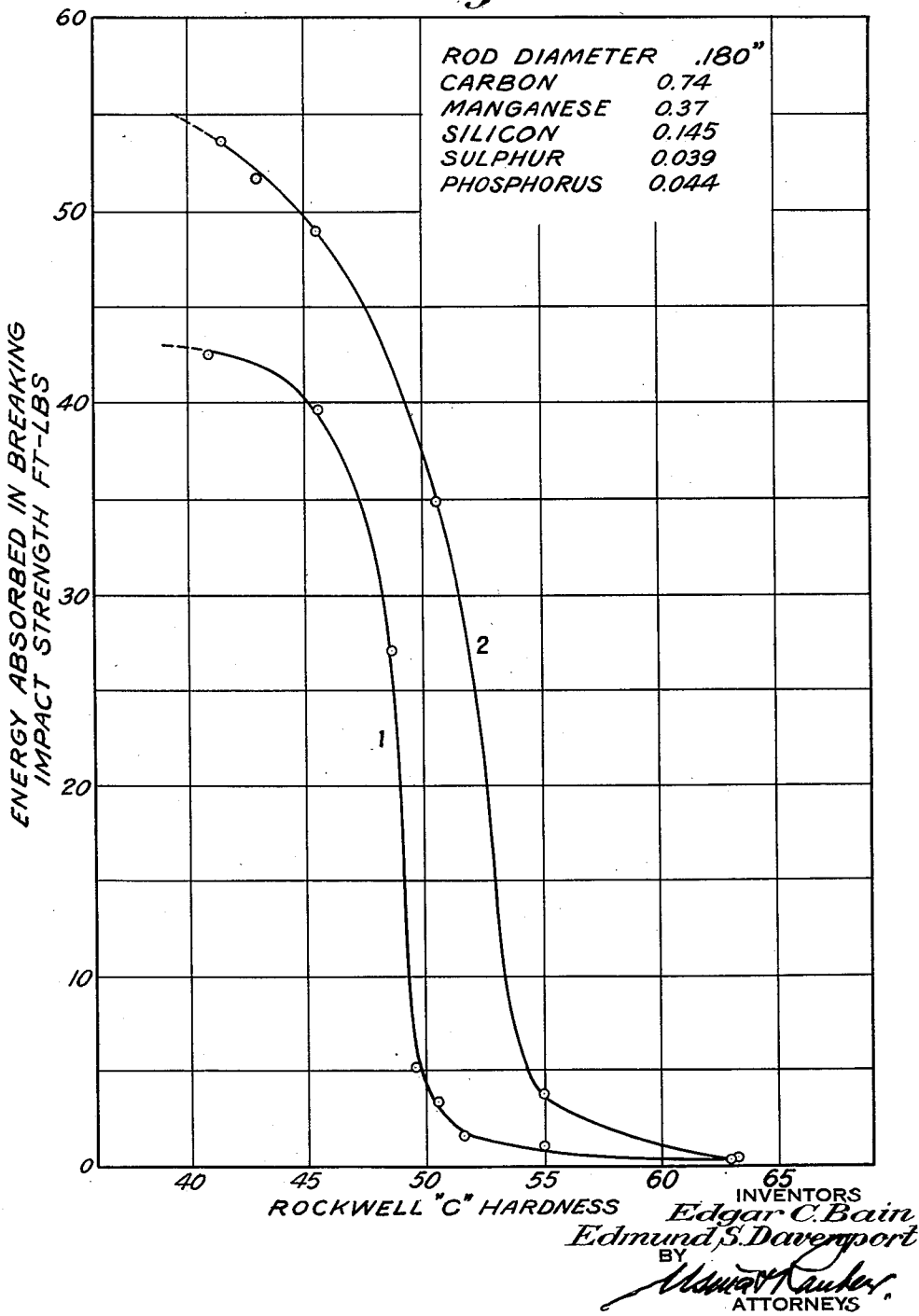
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Fig. 4.



UNITED STATES PATENT OFFICE

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THERMALLY HARDENING STEEL

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Application November 20, 1931
Serial No. 576,398

11 Claims. (Cl. 148—21)

This invention relates to metallurgy and more particularly to the thermal hardening of steels, alloys and the like in which the hardening is obtained by reason of the phenomenon of com-
5 pound particle solution and subsequent precipita-
tion in the metal at the various appropriate tem-
peratures. More specifically the present inven-
tion relates to all carbon and to all alloy steels in
10 which the carbon content thereof may vary in
specific amounts up to values as high as common-
ly employed, for example 2% or 3%, and in which
the alloying elements are not present in amounts
sufficient to inhibit the phenomenon of austenite
15 formation at elevated temperatures nor to pre-
vent the conversion, at lower temperatures, of
the austenite thus formed into the well known
crystal forms of pearlite, sorbite, troostite, mar-
tensite or the like.

One of the objects of the present invention is
20 to provide a new method of thermally hardening
carbon and alloy steels and the like.

Another object of the present invention is to
provide an improved thermally hardened carbon
or alloy steel product.

25 Still another object of the present invention
is to adapt the novel thermal hardening method
of the present invention to the hardening of
fabricated products such as steel wire, rope, rods,
sheet, plate, cutlery, tools, dies, ball-bearings, ma-
30 chine parts, railroad rails and the like.

Other objects and advantages will be apparent
as the invention is more fully disclosed.

In accordance with the objects of the present
invention we have discovered that by the proper
35 control of the transformation of austenite to
crystal structures stable at temperatures below
the so-called transformation temperature of
steel, but above the temperature of so-called mar-
tensite formation a hardened steel product can
40 be obtained which is superior to the hardened
steel products produced by the heretofore em-
ployed quench hardening methods wherein mar-
tensite is utilized as a hardening constituent.

When a carbon or alloy steel mass is quenched
45 from a temperature above its transformation
temperature range, at which temperature the
steel is in the so-called austenitic form, to a
temperature below this range, the rate of conver-
sion of the austenite to pearlite, sorbite, troostite
50 or martensite crystal structures which are formed
at the lower temperature varies markedly. In
general it may be said that there are two zones
of rapid austenite conversion. With carbon or
low alloy steels one conversion zone lies at a
55 temperature approximating 1200° F. to 900° F.

at which the relatively soft pearlite structure is
formed. The second zone lies in the temperature
range approximating 300° F. or below, wherein
rapid conversion of austenite to martensite is
obtained.

Between these temperature zones, the rate of
conversion of austenite to sorbite, troostite or to
admixtures of these with fine pearlite, is relative-
ly slow, and, in general, may be said to decrease
65 with decrease in temperatures from temperatures
approximating 1000° F. to temperatures approxi-
mating 400° F. Below this temperature range the
rate of conversion to martensite becomes rapidly
accelerated to become, at temperatures approxi-
70 mating 200° F. and below, a matter only of sec-
onds, rather than of minutes or of hours.

The specific temperatures which compass the
two zones of rapid conversion of austenite to
pearlite and of austenite to martensite are found,
in any given steel alloy, to depend in part upon
75 the carbon content and also upon the specific
alloy constituents present. The specific rates
of conversion of the austenite at the intermediate
temperatures to the troostite and fine pearlite (or
sorbite) admixtures also markedly vary with vari-
80 ations in the carbon and specific alloy content
of the steel alloy.

It can be generally stated, however, that after
the steel has been rapidly quenched through the
temperature zone at which rapid pearlite conver-
85 sion is obtained and the quenching terminated
at a temperature above that of rapid martensite
conversion, it thereafter may be maintained at
this intermediate temperature for relatively pro-
longed intervals of time before total conversion of
90 the austenite to the specific crystal structure
characteristic of that temperature is obtained,
and that the specific time interval required in-
creases with decreased temperatures down to
about 300° F. In general the lower the tempera-
95 ture of the transformation the harder the prod-
uct of the transformation, ranging from pearlite
10–15 Rockwell C to martensite 63–68 Rockwell C.

We have discovered that a steel product hard-
100 ened by the practice of the present invention has
improved physical properties as indicated by a
higher impact strength, increased ductility, etc.
than steel products of the same composition hard-
ened to the same degree by prior art quench and
105 temper methods.

This increase in impact strength is due we
believe to the fact that during the quench to
these low temperatures the conversion of austenite
to martensite is accompanied by certain volume
110 changes which set up severe internal stresses and

strains in the metal body thereby developing cracks and fissures. Occasionally these may only be detected microscopically.

By the practice of the present invention the development of these cracks and fissures is substantially eliminated and the thermally hardened metal body is thereby greatly improved in ductility and impact strength.

We have adapted the novel thermal hardening process of the present invention to various fabricated articles comprised of carbon or of alloy steels such as wire, cable, sheet, strip, rods, steel rails, beams, plates, cutlery, tools, dies, ball-bearings, machine parts and the like. As a specific embodiment of the practice of the present invention we will disclose the method we have devised in the heat treatment of wire.

Before specifically disclosing the same reference should be made to the following drawings wherein:

Fig. 1 is a schematic view of apparatus adapted for the thermal hardening of wire, rope or cable, strip metal and the like;

Fig. 2 is a chart illustrating the thermal hardening time curve for one type of steel; and

Fig. 3 is a chart illustrating the relative hardness of six common steel alloys when hardened at various constant temperatures in accordance with the present invention. Curve B represents the steel of Fig. 2.

Fig. 4 is a chart showing the marked improvement in the impact strength for equivalent hardnesses in a steel treated by the present invention over the same steel quenched and drawn by prior art methods.

Referring to Fig. 1, the apparatus disclosed therein comprises a preheating furnace 1 and a hardening bath 2 to quench to temperatures below the temperature of rapid pearlite formation the wire cable or strip as it emerges from furnace 1, the precise quenching temperature being determined by the desired hardness and the specific steel alloy composition. Wire 5 (cable or strip) is carried on unwinding reel 6, through preheating furnace 1 and hardening bath 2 to winding reel 7 in any convenient manner substantially as shown. Means (not shown) are provided to wind the wire upon reel 7 at a controllably variable rate. Thermostat control means 8 and 9 are provided for furnace 1 and bath 2 to maintain predetermined desired temperatures therein. Preferably, electrical heating means are employed for furnace 1 and bath 2 as indicated but other heating means may be employed, if desired.

If desired, an inert or reducing atmosphere may be provided in furnace 1 or over bath 2 to prevent undue surface oxidation or corrosion of the wire, cable or strip being conditioned.

If desired, additional quenching means may be provided intermediate furnace 1 and quenching bath 2. Some steel compositions may require only a slight temperature reduction and an air blast cooling may be used. Other steel compositions may require an oil or water quench for which other arrangements may be made. Water may be sprayed upon the surface of the wire or the wire may be caused to dip for a brief interval of time below the surface of a water or oil bath. With strip or sheet material we may use water cooled rolls to obtain the desired quenching action. In general, and particularly with sections this additional quenching means may be omitted.

In some instances it may be desirable to ob-

tain moderate hardness by permitting a part of the austenite to transform to martensite by quenching after having permitted the bulk of or a desired proportion of the same to transform over to pearlite, sorbite or troostite crystal forms in the hardening bath 2. Therefore by proper adjustment of the temperatures and the rate of travel of the wire, cable or strip 5 this additional quenching may be obtained by providing an air blast, water or oil bath between quenching bath 2 and winding reel 7. Where the time interval in bath 2 is sufficient to obtain entire conversion of the austenite to the crystal forms other than martensite, martensite then will not be formed when and if the wire 5 is quenched from the hardening bath temperatures before passing to the winding reel 7.

Referring to the hardening bath 2, the material 10 comprising the same is preferably comprised of lead or a lead alloy adapted to give the desired fluidity at the predetermined hardening temperature, and container 11 may be comprised of any suitable material non-reactive therewith. Electrical heating elements 12 also are subject to wide variation in type and manner of control without departing essentially from the nature and scope of the present invention. Means 13 adapted to submerge the wire 5 below the surface of the bath 10 may be comprised of the common rotatable pulley type indicated or may be any other convenient means as desired. Bath 2 may be sealed from the atmosphere or open thereto as desired, and a superposed inert or a reducing gas may be employed, if desired.

A steel wire of the composition indicated in Figs. 2 and 4 heat treated to develop a hardness of 50 Rockwell C by the present invention developed a tensile strength of 283,000 pounds per sq. in. accompanied by a reduction in area of 34.5%, whereas the same steel alloy treated by the conventional quench and temper method developed a tensile strength of only 247,000 pounds per sq. in. and 0.7% reduction in area. It will be seen that high ductility is obtainable through the use of the present invention without sacrifice of high tensile strength.

In Fig. 2 we have set forth the thermal hardening time curve for a typical commercial steel alloy comprised of 0.78% carbon, 0.36% manganese, 0.160% silicon, 0.036% phosphorous, 0.048% sulphur and the balance substantially iron. In the Fig. 2, time is plotted on a logarithmic scale rather than on a linear scale in order to condense the curve to representable proportions. This type of curve is well known in the art and can be readily interpreted by those skilled in the art and is resorted to when necessary to illustrate great disparities in time intervals under the conditions portrayed by the chart.

From this chart it will be noted that the time interval for complete conversion of austenite to pearlite at 1300° F. comprises approximately seven minutes; the time for complete conversion of austenite to fine pearlite at 1000° F. comprises approximately four seconds; the time for complete conversion of austenite to troostite at 600° F. comprises approximately ten minutes; the time for complete conversion of austenite to its decomposition product at 400° F. comprises approximately twenty-four hours and the time for complete conversion of austenite to fully hard martensite at 100° F. is of the order of one or two seconds.

In Fig. 3 we have indicated the hardness obtained on six common steels when hardened at

various constant temperatures in accordance with the present invention in which curve B represents the steel of Fig. 2. It will be noted from curve B that a Rockwell hardness of about C 15 is obtained by causing this steel to transform completely at a temperature of 1300° F. Similarly a hardness of about C 36 results when the transformation from austenite takes place at 1000° F., a hardness of about C 51 when the transformation takes place at 600° F., a hardness of about C 57 when transformation takes place at 400° F. and a full martensitic hardness of about C 64 when the transformation takes place at 100° F. or below.

From the curves shown in Figs. 2 and 3 it is believed clear that where a certain hardness, for example Rockwell C 51, is desired in a steel product of the steel composition of Fig. 2, the same may be obtained by quenching the steel to a temperature approximating 600° F. and maintaining it at that temperature for about ten minutes.

The steel product thus obtained will have an impact strength materially higher than the impact strength of a similar steel hardened to the same degree by prior art quench and temper methods. This is illustrated with particularity in Fig. 4.

In Fig. 4 curve (1) shows the impact strength of a steel as obtained by the quench and temper method. Curve (2) shows the impact strength of the same steel as obtained by the practice of the present invention. The steel composition of each is substantially identical to that of the steel of Fig. 2.

Referring to Fig. 4 where a hardness of Rockwell C 51 is obtained the impact strength of a quench and tempered steel approximates 3 to 4 foot pounds with a rod diameter of .180 inch. A similar steel rod hardened by the practice of the present invention to the same hardness (Rockwell C 51) has an impact strength approximating 35 foot pounds.

While we have disclosed as a specific embodiment of the practice of the present invention, the adaptation of the same to the hardening of wire, rope, cable or strip, it is not to be construed that we are limited thereby, as the specific invention is subject to many adaptations and modifications in the heat treatment of other steel products such as rails and shapes, cutlery, machine parts, etc. and such adaptations and modifications of the steps of the present thermal hardening method are contemplated as may be included within the scope of the accompanying claims.

What we claim is:

1. The method of thermally hardening carbon and alloy steels which comprises quenching the same from a temperature above the critical temperature range to a temperature below the temperature of rapid pearlite formation but above that at which rapid conversion of austenite to martensite is obtained, and in thereafter maintaining the quenched steel at a temperature above the temperature of rapid martensite formation and below the temperature of rapid pearlite formation for a time interval sufficient to obtain substantial conversion of the austenite to crystal structures other than pure martensite characteristic for the temperature of heat treatment and then cooling to atmospheric temperatures.

2. The method of thermally hardening carbon and alloy steels which comprises quenching the steel from a temperature above the critical tem-

perature range to a temperature below about 1000° F. but above 300° F. and in thereafter maintaining the steel at a temperature within that range for a time interval sufficient to obtain substantial conversion of the austenite to crystal structures other than pure martensite characteristic for the temperature of heat treatment and then cooling to atmospheric temperatures.

3. The method of thermally hardening carbon and alloy steels which comprises quenching the steel from a temperature above the critical temperature range of the alloy to a temperature below approximately 1000° F. but above the temperature of rapid martensite formation and maintaining the steel at such an intermediate temperature for a time interval sufficient to obtain substantial conversion of the austenite to crystal structures other than pure martensite characteristic for the temperature of heat treatment and then cooling to atmospheric temperatures.

4. The method of thermally hardening carbon and alloy steels which comprises quenching the steel from a temperature above the critical temperature range of the alloy to a temperature below approximately 1000° F. but above the temperature of rapid martensite formation, holding the steel at such intermediate temperature for a time interval sufficient to obtain substantial conversion of the austenite to crystal structures other than pure martensite characteristic for the temperature of heat treatment and thereafter quenching the steel to temperatures below about 300° F.

5. The method of thermally hardening steel wire, rope, cable, strip and the like which comprises heating the wire to temperatures above the critical temperature range, quenching the wire to temperatures above about 300° F. but below about 1000° F., holding the wire at that temperature for a predetermined desired time interval sufficient to obtain substantial conversion of the austenite to crystal structures other than pure martensite characteristic for the temperature of heat treatment and then cooling to atmospheric temperatures.

6. The method of thermally hardening steel wire, rope, cable, strip and the like which comprises heating the wire to temperatures above the critical temperature range, quenching the wire to temperatures above about 300° F. but below about 1000° F., holding the wire at that quench temperature for a predetermined desired time interval sufficient to obtain substantial conversion of the austenite to crystal structures other than pure martensite characteristic for the temperature of heat treatment and thereafter quenching to room temperatures.

7. The method of thermally hardening steel wire, rope, cable, strip and the like which comprises heating the wire in a reducing atmosphere to temperatures above the critical temperature range, quenching the wire to temperatures above about 300° F. but below about 1000° F., holding the wire at that quench temperature for a predetermined desired time interval sufficient to obtain substantial conversion of the austenite to crystal structures other than pure martensite characteristic for the temperature of heat treatment and then cooling to atmospheric temperatures.

8. The method of thermally hardening steel wire, rope, cable, strip and the like which comprises heating the wire in an inert atmosphere to temperatures above the critical temperature range, quenching the wire to temperatures above

about 300° F. but below about 1000° F., holding the wire at that quench temperature for a pre-determined desired time interval sufficient to obtain substantial conversion of the austenite to crystal structures other than pure martensite characteristic for the temperature of heat treatment and then cooling to atmospheric temperatures.	10. As an article of manufacture, steel having the composition and hardened by the method, substantially as defined in claim 4.	
9. As an article of manufacture, steel having the composition and hardened by the method, substantially as defined in claim 1.	11. As an article of manufacture, steel having the composition and hardened by the method substantially as defined in claim 1, said steel being characterized by being substantially free from martensite and by high ductility and impact strength.	80
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