UNITED STATES PATENT OFFICE.

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ART OF HARDENING AND TOUGHENING STEEL.

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To all whom it may concern:

Be it known that I, JAMES CHURCHWARD, a subject of the King of Great Britain, residing in the borough of Manhattan, in the city, county, and State of New York, have invented certain new and useful Improvements in the Art of Hardening and Toughening Steels, of which the following is a specification.

This invention relates to a process of making castings of steel and the products made from castings of steel hard and tough; and while applicable to castings or products of castings for any use or purpose the process is especially applicable to the production of armor-plates, bank vaults and safes etc.

In explaining the carrying out of the invention it will suffice to describe the actual process which is preferably employed in making a hardened and toughened steel plate—such, for example as an armor-plate suitable for a war-ship, although the procedure may be slightly varied, as well as the proportions of the ingredients employed when dealing with castings for this and for other uses.

The composition consists of a steel alloy containing parts or percentages of nickel, chromium, tungsten, vanadium and manganese, and may vary in proportion by weight as follows:—

Steel from	96.20	parts to	79.50	parts
Nickel, from	2.00	" "	10.00	"
Chromium, from	1.00	" "	5.00	"
Tungsten, from	.50	" "	2.00	"
Vanadium, from	.15	" "	1.50	"
Manganese from	.15	" "	2.00	"
	100.	"	100.	parts.

For making an exceptionally hard and tough armor-plate the following are suitable proportions designated by weight:—

Steel, containing .20% carbon	87.30	parts
Nickel,	5.00	"
Chromium,	5.00	"
Tungsten,	1.00	"
Vanadium,	1.00	"
Manganese,	.70	"
	100.	parts

The carbon may be added in many known ways and it may vary in the body of the mass from .20% to 1.25% according to the uses for which the article is intended.

If carbon steel is used as a stock, or if iron is used as the stock both should be practically free from phosphorus and sulfur and absolutely free from copper. The carbon may vary in the body of the plate from .20% to .25%. For alloys ferros may be used instead of the pure metals, as long as they do not contain a percentage of carbon that will carry the carbon beyond .25% in the plate. A larger percentage of manganese than that given above may be used without disadvantage to hardness and toughness, but a larger percentage than what is given will not ordinarily be required.

The stock and alloying metals may be melted together up to 1960° C., if pure metals are used, but if ferro alloying metals are used a temperature of 1600° C. to 1960° C. is sufficient, dependent on the percentage of the carbon and alloying metal contained in the ferros. It may be found more advantageous to sink both the chromium and tungsten in the metal bath before tapping the furnace, and to add the vanadium to the ladle at the time of pouring. When the chromium is added to the metal bath the temperature of the bath should be 1960° C. if pure metallic chromium is used or 1600° C. to 1960° C. if ferro-chromium is used. The melting of the chromium should be carefully ascertained and thirty-five minutes after its complete melting the furnace should be tapped and the heat run out into the ladle. The tungsten should be added fifteen minutes before tapping the furnace and with it a percentage of manganese. A percentage of the chromium will be lost in the melting but this is allowed for in the percentage given above. There will be much less loss of chromium if the temperature of the metal bath is at 1960° C. for metallic chromium and 1600° C. to 1960° C. for ferro-chromium when the chromium is sunk than there would be if the metal bath was two or three hundred degrees lower. When in the ladle, the heat should be killed down to a point where a solid casting will be insured. This point is so well known to those versed in the art that nothing is necessary to be said about it except a word of caution.

The mold can be of the ordinary type used for casting armor plate. When the casting shall have been in the mold long enough for it to set or harden sufficiently to be handled, it should be taken out and laid on its side well supported to prevent buckling until it is cold enough for re-heating for pressing, and while cooling it should be kept free from drafts and so suspended or supported that it will have a free access of air on all sides so that the cooling of the ingot is even throughout. When cold enough to re-heat for pressing it should be put into the furnace and gradually raised to a temperature of 1149° C. In the press it should be reduced to at least one-third of its original thickness. Pressing plates in this manner is not new, and obviously the plate may be compacted by other equivalent and known means, as rolling or forging. The last inch of the compression should be made when the plate is at a temperature of 900° C. or a little under. After pressing, the plate should have its edges squared off and then be put into the annealing and super-carburizing oven. The plate should be on a bed of carbonizing material and be completely muffled. It should be placed in an oven with a temperature of about 500° C. and then slowly and gradually raised to a temperature of 1090° C. to 1100° C. This will take from six to sixteen days, dependent on the thickness of the plate. A six inch plate takes about twelve days. At the end of the time of super-carburizing, the fires should be turned off, the oven banked and the plate slowly cooled. When cool enough to handle it should be drilled to ascertain the depth of super-carburizing and the drillings analyzed to determine the percentage of carbon in the face. There should be 1% of carbon in the face and the depth of super-carburizing should be at least one and one-half to two inches. If not sufficiently super-carburized it should go back into the oven again and have another treatment. After the super-carburizing and annealing the plate can be tooled. After the tooling on account of the molecular disturbance of the particles, caused by the high temperature necessary for annealing and super-carburizing, shown as microscopical segregations, the plate should undergo a heat treatment, in the form of heat-waves or heatings, and each heating or heat-wave should be carried to within 50° C. of the retardation points of each alloy commencing with the alloy having the highest retardation point and ending with the alloy having the lowest. It is believed that a temperature of 900° C. affects chromium and tungsten. A temperature of 750° C. is believed to affect manganese and a temperature of 600° C. is thought to affect vanadium.

The plate should be cooled after each heat or temperature in a bath composed of either oil or a phenol and a fatty substance. Preferably, for the purpose of treating the plate produced as described above, the bath may be composed of carbolic acid, thirty parts, linseed oil seventy parts, total one hundred parts. The bath should be kept as cool as possible with either a jacket of ice or running water surrounding it. The object is to cool the plate quickly and it should remain in each bath until thoroughly cooled. The proportion of liquid in the bath to the size of the plate is not deemed very important, as long as the plate or casting is completely submerged, but a proportion of fifty cubic inches of liquid bath to one cubic inch of metal makes a good working bath. The proportion of the ingredients of the bath should be maintained by adding one or the other from time to time to make up for what has been lost.

In the bath linseed oil may be replaced by other oils or fatty substances or glycerin (glycerol) and the word fatty substance is here intended to include glycerin.

For carbolic acid (phenol hydroxid) any phenol or suitable phenol derivative may be employed with good results as creosote (a monohydric phenol) for example. The word "phenol" as herein used is intended to include any one or all of these substances.

One submersion of the plate at each of the temperatures given above—900° C., 750° C. and 600° C.—is sufficient for toughening and hardening all metals other than armor plate, but in armor plate a glass hard face is required, and to produce this the plate should be heated again to 600° C. and receive either a "blister" hydraulic water spray bath or a bath composed of phenol, fatty substance and mercury. A suitable bath for this is 50% mercury mixed with 50% fat, forming a layer of about one inch on the bottom of the bath, and this layer to be covered with two or three feet of oil or phenol and oil. The plate must be submerged in this bath so that its face rests on the mercury and fat. In all cases where the plate is re-heated after super-carburizing it should rest on a thin layer of super-carburizing material in the oven and should also be muffled to prevent oxidizing of the carbon in the plate.

This invention is not limited to a carbon steel as a basic metal or stock for the alloy. Iron may be used as stock and formed into steel at the time of making the plate.

In cases where all tendency to brittleness is to be particularly avoided the element tungsten may be omitted.

Having thus described my invention, I claim—

1. The herein described improvement in the art of hardening and toughening metals, which consists in forming an alloyed steel which contains parts or percentages of nickel, chromium, tungsten, manganese and vanadium, melting the same together and carrying the temperature of the metal bath to about 1960° C. if pure metallic chromium is used or from 1600° to 1960° C. if ferro chro-

mium is used, for about 35 minutes before tapping the furnace.

2. The herein described improvement in the art of hardening and toughening metals, which consists in forming an alloyed steel which contains parts or percentages of nickel, chromium, tungsten, vanadium and manganese, carrying the temperature of the metal bath to about 1960° C. if pure metallic chromium is used, or from 1600° C. to 1960° C. if ferro chromium is used, for a short period of time and then casting the same in a mold.

3. The herein described improvement in the art of hardening and toughening metals, which consists in forming a steel containing parts or percentages of nickel, chromium, tungsten, vanadium and manganese, then casting the same in a mold, then pressing the same, and finally subjecting the casting to a succession of alternate heatings and quenchings, the successive heatings being at graduated temperatures.

4. The herein described improvement in the art of hardening and toughening metals, which consists in forming a steel containing parts or percentages of nickel, chromium, tungsten, vanadium and manganese, then casting the same in a mold, then pressing the same, and finally subjecting the casting to a succession of alternate heatings and quenchings, the heating corresponding to the retardation points of the alloying metals, and being at temperatures a little below said retardation points.

5. The herein described improvement in the art of hardening and toughening metals, which consists in forming a steel containing parts or percentages of nickel, chromium, tungsten, vanadium and manganese, then casting the same in a mold, then pressing the same, and finally subjecting the casting to a succession of alternate heatings and quenchings, the successive heatings being graduated to temperatures a little below the retardation points of the several alloying metals, commencing with a temperature that reaches to within 50° C. of the retardation point of the alloying metal having the highest retardation point, and continuing down in succession each time within 50° C. of the retardation point of the respective alloying metals.

6. The herein described improvement in hardening and toughening metals, which consists in forming a steel containing parts or percentages of nickel, chromium, tungsten, vanadium and manganese, then casting the same in a mold, then pressing the casting, then super-carburizing the pressed casting, then subjecting the casting to a succession of alternate heatings and quenchings, the successive heatings being at graduated temperatures, commencing with a temperature a little below the retardation point of the alloying metal having the highest retardation point and continuing down in succession to a temperature a little below the retardation points of the other alloying metals and finally subjecting the plate when at a temperature of from 550° C. to 650° C. to water spray or blister bath.

7. The herein described improvement in the art of hardening and toughening metals, which consists in forming a steel containing parts or percentages of nickel, chromium, tungsten, vanadium and manganese, then casting the same in a mold, then pressing the casting, then super-carburizing the pressed casting, then subjecting the casting to a succession of alternate heatings and quenchings, the successive heatings being at graduated temperatures, commencing with a temperature a little below the retardation point of the alloying metal having the highest retardation point and continuing down in succession to a temperature a little below the retardation points of the other alloying metals, and finally immersing the casting when at a temperature of between 550° C. and 600° C. in a bath containing a compound of mercury and fat and covered with oil or oil and a phenol.

8. The herein described improvement in the art of hardening and toughening metals, which consists in forming a steel containing parts or percentages of nickel, chromium, vanadium, and manganese, then casting the same in a mold, then pressing the casting, then super-carburizing the pressed casting, then subjecting the casting to a succession of alternate heatings and quenchings, the successive heatings being at graduated temperatures, commencing with a temperature a little below the retardation point of the alloying metal having the highest retardation point and continuing down in succession to a temperature a little below the retardation points of the other alloying metals and finally subjecting the plate when at a temperature of between 550° C. to 650° C. to a water spray or blister bath.

9. The herein described improvement in the art of hardening and toughening steel and iron, which consists in fusing an alloy of carbon steel, nickel, chromium, manganese, tungsten and vanadium, then casting the alloy and then, while still at a suitable temperature, submitting the casting to pressure, and finally subjecting the casting to a succession of alternate heatings and quenchings, the successive heatings being at graduated temperatures.

10. The herein described improvement in the art of hardening and toughening metals, which consists in forming an alloyed steel containing parts or percentages of nickel, chromium, tungsten, vanadium and manganese, melting the same together and carrying the temperature of the metal bath to about 1960 C. if pure metallic chromium or from 1600 C. to 1960 C. if ferro-chromium is

used, for about 35 minutes before tapping the furnace, then casting the same in a mold, then pressing the same, and finally subjecting the casting to a succession of alternate heatings and quenchings, the successive heatings being at graduated temperatures.

In witness whereof I have hereunto signed my name this 8th day of April 1907, in the presence of two subscribing witnesses.

JAMES CHURCHWARD.

Witnesses:
WILLIAM J. FIRTH,
H. G. HOSE.