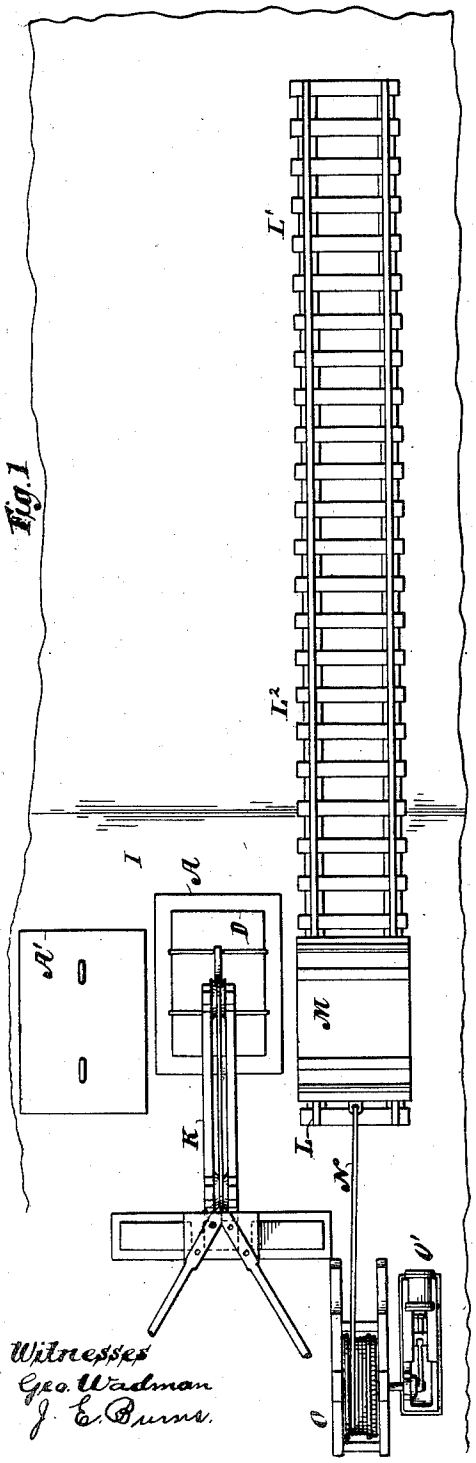
(No Model.) 3 Sheets—Sheet 1.

H. A. HARVEY.

DECREMENTALLY HARDENED ARMOR PLATE.

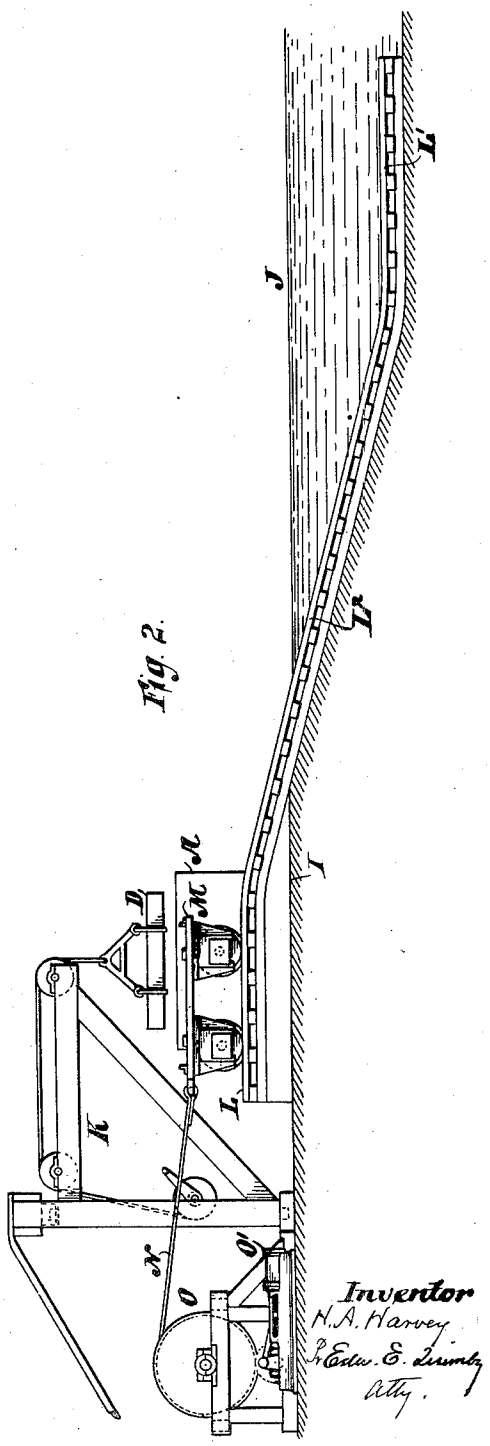
No. 460,262. Patented Sept. 29, 1891.

Fig. 1



Witnesses
Geo. Wadman
J. E. Burns.

Fig. 2.



Inventor
H. A. Harvey
by Edw. E. Lumbard
Atty.

(No Model.) 3 Sheets—Sheet 2.

H. A. HARVEY.

DECREMENTALLY HARDENED ARMOR PLATE.

No. 460,262. Patented Sept. 29, 1891.

Fig. 3.

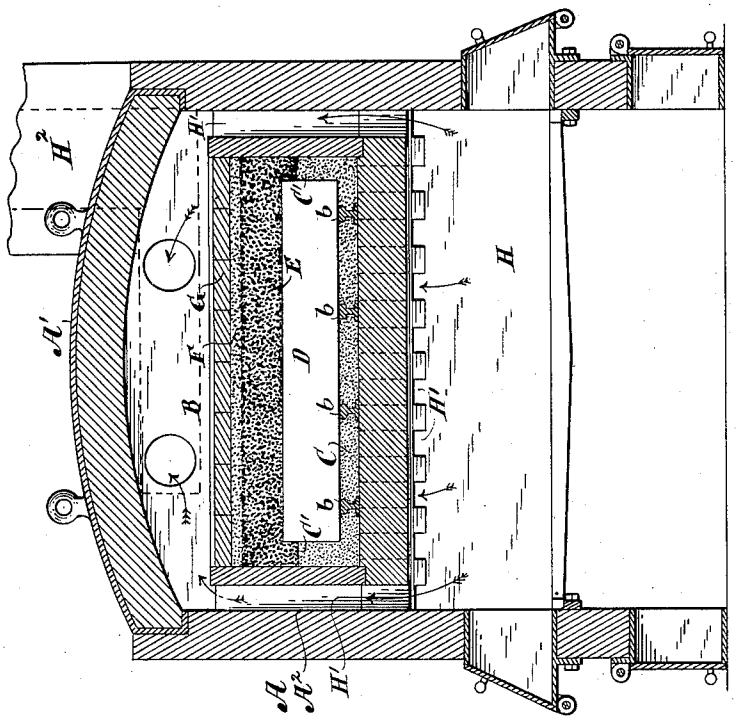
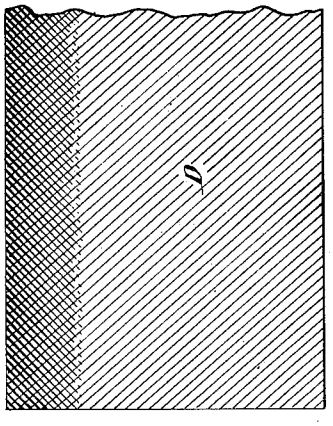


Fig. 4.



Witnesses
Geo. Wadman
J. E. Burns

Inventor
H. A. Harvey
Per Edw. E. Dumby
Atty.

(No Model.) 3 Sheets—Sheet 3.

H. A. HARVEY.

DECREMENTALLY HARDENED ARMOR PLATE.

No. 460,262. Patented Sept. 29, 1891.

Fig. 5.

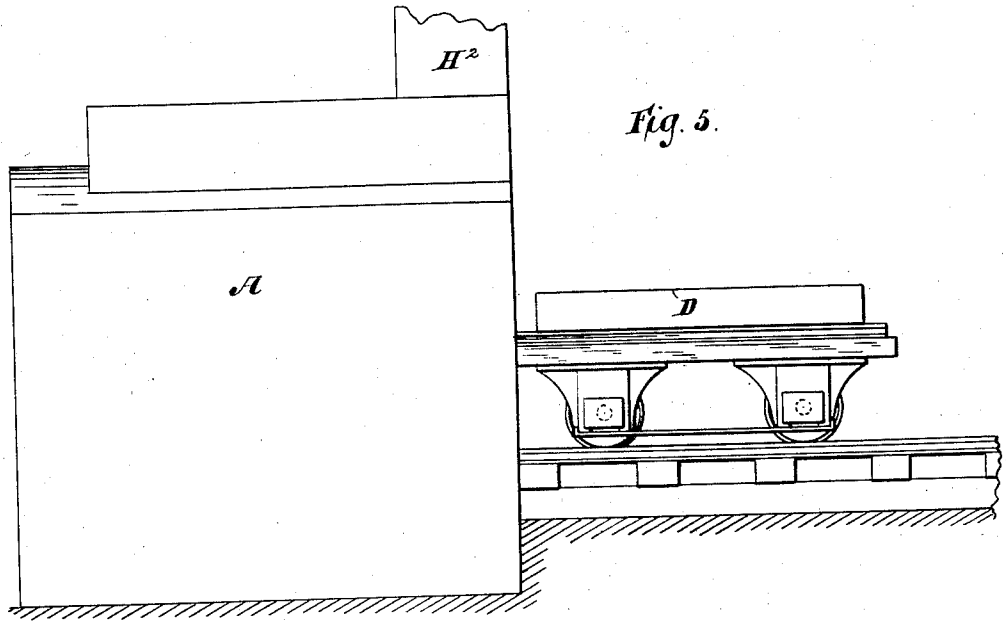
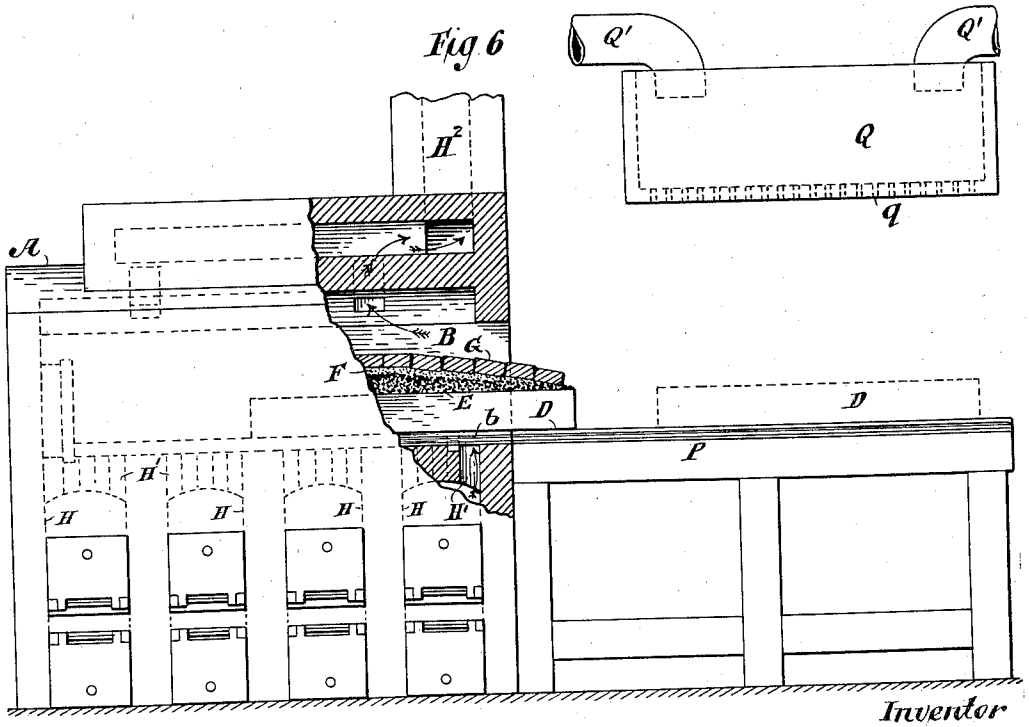


Fig 6



Witnesses
Geo. Wadman
J. E. Burns

Inventor
H. A. Harvey
Per Edw. E. Linthicum
Atty.

UNITED STATES PATENT OFFICE.

HAYWARD A. HARVEY, OF ORANGE, NEW JERSEY.

DECREMENTALLY-HARDENED ARMOR-PLATE.

SPECIFICATION forming part of Letters Patent No. 460,262, dated September 29, 1891.

Application filed April 1, 1891. Serial No. 387,209. (No model.)

To all whom it may concern:

Be it known that I, HAYWARD A. HARVEY, of Orange, New Jersey, have invented certain Improvements in Decrementally-Hardened Armor-Plates and in the Art of Manufacturing the Same, of which the following is a specification.

This invention embraces a method of facilitating the transformation of homogeneous low steel armor-plates into plates which present upon the side intended to receive the impact of projectiles a stratum of tenacious steel of heterogeneous crystalline structure highly and uniformly carburized and excessively hard upon its exposed surface and less and less carburized and gradually diminishing in hardness as the depth from said surface increases. The required transformation is effected by inclosing the low steel plate between a mass of non-carbonaceous granular material on one side and a mass of granular carbonaceous material packed firmly against the other side in a compartment erected within the heating-chamber of a suitable furnace and in then raising the heat of said heating-chamber and maintaining it at a temperature above the melting-point of cast-iron for a period of time sufficient to effect the desired increase in the tenacity of the steel and the supercarburization to the desired extent and depth of the side of the plate against which the granular carbonaceous material is being constantly pressed. The plate is subsequently removed from the furnace and chilled by immersion in a cold bath or otherwise, as hereinafter set forth, whereby its supercarburized side is hardened. The heat to which the plate is subjected during the described treatment is so intense that the plate would be melted but for the granular materials surrounding it, by which all parts of it are protected from the air. The continuous firm compression of the carbonaceous material against the plate during the entire treatment secures the perfect contact of the carbonaceous material with all portions of the adjacent side of the plate and promotes the rapid and uniform supercarburization thereof.

The product of the described treatment, except in respect of its crystalline structure, is a homogeneous armor-plate of highly-tenacious steel, which upon the side intended to receive the impact of projectiles presents a stratum of prescribed thickness which is decrementally carburized, and consequently has an ununiform crystalline structure, and is excessively hard at its exposed surface and gradually diminishes in hardness as the distance inward from its exposed surface increases. The differences in granulation or crystalline structure are those which are respectively incident to the different percentages of carbon present at different depths beneath the surface. The said product is herein designated as a "decrementally-hardened armor-plate," because the hardening process is the final step in its production, and because decremental hardening is dependent upon previous decremental carburization and involves the presence in the finished product of a heterogeneous crystalline structure, which increases its resistance to cleavage.

The treatment is analogous to that described in Letters Patent of the United States No. 376,194, issued to H. A. Harvey January 10, 1888.

As modified for the present purpose the process is conducted as follows: The armor-plate having been formed of the desired size and shape from a comparatively low steel, such as Bessemer steel or open-hearth steel, containing, say .10 to .35 per cent. of carbon, is laid, preferably, flatwise upon a bed of finely-powdered dry clay or sand deposited upon the bottom of a fire-brick cell or compartment erected within the heating-chamber of a suitable furnace. The plate may be so embedded that its upper surface is in the same plane with the upper surface of those portions of the bed of clay or sand which adjoin the sides and ends of the plate, or the plate may, if desired, be allowed to project to a greater or less distance above the surface of the clay or sand. In either case the treating-compartment is then partially filled up with granular carbonaceous material, which, having been rammed down upon the plate, is covered with a stratum of sand, upon which there is laid a covering of heavy fire-bricks. The furnace is then raised to an intense heat, which is kept up for such period of time as may be required for the absorption by the metal adjoining the upper surface of the plate of, say, an additional one per cent.

(more or less) of carbon, or, in other words, the quantity of carbon, in addition to that originally present, which may be necessary to enable the said metal to acquire the capacity of hardening to the desired degree. The temperature of the heating-chamber outside of the treating-compartment is brought up to a height equal to or above that required to melt cast-iron, and is kept up for a greater or less length of time, according to the depth of the stratum of steel which it is intended to charge with an excess of carbon. This period, however, will of course vary according to the efficiency of the furnace.

The degrees of efficiency possessed by different furnaces can only be satisfactorily ascertained by actual trial. When ascertained, the reproduction of given results merely requires the re-establishment of the conditions as to time and temperature under which said results have been previously observed to be obtained. This involves merely the maintenance of the furnace at a heat sufficient to melt cast-iron for the period which by previous observation has been ascertained to be the period required for adding to the tenacity of the steel and for the supercarburization of the plate to the prescribed extent and depth. For example, a plate, say, ten and one-half inches in thickness, composed of a comparatively low steel containing, say, .35 per cent. of carbon, may be charged with additional quantities of carbon, gradually varying in amount from, say, one-tenth of one per cent. at a depth of three inches beneath the surface of the exposed side of the plate to one per cent. at the surface thereof by a continuance of the treatment for a period of, say, one hundred and twenty hours after the furnace has been raised to the required temperature.

The statement that the heat at which the furnace is maintained is sufficient to melt cast-iron is to be regarded as approximate merely. The more intense the heat the better, and while it will of course be understood that the longer the treatment is continued the greater will be the depth to which the carbon penetrates beneath the surface against which the carbonaceous material is packed, it is also to be remarked that the penetration of the carbon is greatly facilitated by the continuous firm compression of the carbonaceous material against the plate. As a general rule the thicker the armor-plate the greater will be the permissible depth of supercarburization. A ten-and-a-half-inch plate and a depth of supercarburization of three inches are herein referred to merely for the purpose of illustration. After the conclusion of the carburizing treatment the plate is taken out of the furnace, and without removal of the carbonaceous material from its surface is allowed to cool down to the proper temperature for chilling. During the cooling operation the carbonaceous material protects the hot supercarburized surface from the air, and thus prevents the formation of scale, which, if present, would interfere with the subsequent hardening of the metal beneath it. The carbonaceous material, however, may without injurious consequences be temporarily removed from and quickly replaced upon small portions of the supercarburized surface for the purpose of exposing them for observation. When it is seen that the supercarburized surface is so far cooled down as to have a dull cherry-red color, the carbonaceous material is quickly removed, and the plate is then chilled by being sprayed with torrents of cold fluid or by being submerged and kept in motion until cold in a large body of cooling-fluid—as, for example, a more or less rapidly-running stream or river of fresh water or a tidal current of salt water. The exercise of this precaution insures the subsequent uniform hardening of the supercarburized surface of the plate.

The accompanying drawings, symbolically illustrating a furnace suitable for the described treatment and mechanical appliances for handling the plate and for facilitating the chilling operation, are as follows:

Figure 1 is a top view of a furnace provided with a removable cover, erected upon the bank of a river or other body of water in suitable proximity to a crane and to a car-track extending down the bank along the bottom of the stream or body of water, showing a car upon which the treated plate is deposited by means of the crane, a windlass-chain connected with the car, and an engine for operating the windlass, and thereby controlling the movements of the car up and down the inclined track. Fig. 2 is a side elevation, partly in section, of the plant represented in Fig. 1. Fig. 3 is a transverse vertical section of the furnace, showing the armor-plate and the cell or compartment containing the bodies of material in which the armor-plate is inclosed. Fig. 4 is a transverse section of a portion of an armor-plate shaded to symbolically represent variable degrees of supercarburization at different depths beneath the surface upon the side intended for exposure to the impact of projectiles. Fig. 5 is an elevation of a treating-furnace illustrating a mode of arranging the track so that the armor-plate can be taken out of one end of the furnace directly onto the car upon which it is supported during the chilling operation. Fig. 6 illustrates a provision for chilling the plate by spraying it with torrents of cooling-fluid, and shows a stationary platform extending from one end of the furnace to a position beneath the spraying-tank.

The drawings represent a furnace A, which may be provided with a movable cover A′, as symbolically represented in Figs. 1, 2, and 3, or which may be constructed with reference to having one or both of its end walls removed to facilitate the removal of the plate in a horizontal direction, as illustrated in Fig. 6. Within the heating-chamber A^2 of the fur-

nace is the treating cell or compartment B, which is preferably provided at the bottom with a series *b* of parallel rails, which are embedded in a stratum of sand C of the same height as the rails and are intended for the support of the armor-plate D. The space around the ends and sides of the armor-plate is also filled with sand C′ nearly or quite to the top of the plate. A stratum of granular carbonaceous material E, rising to a height of, say, eight inches above the upper surface of the plate D, is tightly rammed down onto the top of the plate and is surmounted by a stratum of, say, two inches of sand F, covered by a layer G of heavy fire-brick. The stratum of sand F and the layer of fire-brick G not only protect the carbonaceous material from the fire, but serve to weight the carbonaceous material down upon the plate.

The treating-compartment B is heated by the flames and hot products of combustion from the fire-chamber H, which are led upward through the flues H′ and directed inward over the tops of the treating-compartment and finally discharged into the chimney or smoke-stack H^2.

In Fig. 1 the furnace is represented as erected upon the sloping bank I of a river or body of water J in suitable proximity to a crane K and a car-track L, extending down the bank and along the bottom of the body of water J. When the carburizing treatment is completed, if the furnace shown in Fig. 1 is employed, the cover A′ is removed, the fire is drawn, and the furnace allowed to cool off preparatory to the removal of the superincumbent materials from the plate D and the lifting of the plate D by means of the crane out of the treating-compartment and its deposit upon the car M. The track L is so inclined that the car when freed to the influence of gravity will run down into the water and a greater or less distance along the submerged portion L′ of the track. The car is hauled up the inclined portion L^2 of the track by means of a windlass-chain N, fastened to the shore end of the car M and wound around the drum of the windlass O, which is operated by the engine O′. The chilling of the plate is effected by alternately hauling the car up the inclined portion L^2 of the track and allowing it to run backward by its own gravity.

In dealing with a heavy plate it will usually be found more convenient to construct the furnace with reference to the removal of one or both of its end walls to facilitate the removal of the plate from the treating-furnace by sliding it in a horizontal path onto a car, as indicated in Fig. 5, or onto a platform P, which is on a level with the top of the rails *b* at the bottom of the treating-compartment, as indicated in Fig. 6. The plate having been thus deposited upon the car, the latter can be run down into the water, as already described, or can be run under a spraying-tank Q, or the platform P may be prolonged sufficiently to reach from the end of the furnace to a position beneath the spraying-tank, as illustrated in Fig. 6. The spraying-tank has a perforated bottom *q*, which is elevated, say, ten feet above the platform on which the plate is supported. The tank is supplied with water or other liquid by a service pipe or pipes Q′ of sufficient capacity to supply a quantity greater than the quantity discharged by the apertures in bottom *q* thereof. After the carbonaceous material has been removed from the top of the plate and when the plate, having been placed beneath the spraying-tank, has so far cooled down as to have a dull-red color, the tank is supplied with the cooling-fluid, which is discharged therefrom in jets from the perforated bottom directly upon the plate.

With a furnace of the character shown in the drawings a period of about forty-eight hours will be required to bring up the heat to the required point, and such heat will be required to be kept up about one hundred and twenty hours. A further period of four or five hours will ordinarily be required after the fire has been drawn to remove the plate from the furnace and have it cool down to the desired dull-red color. The spraying operation will be required to be continuously kept up for a period of about four hours in order to effect and preserve the chilling of the supercarburized surface until the remainder of the plate has become completely cool. A plate of ten and a half inches in thickness thus treated will be found to be excessively hardened upon its supercarburized surface and at the same time to be remarkably tenacious, so that a hardened projectile of, say, six inches diameter, weighing one hundred pounds, fired at it with a striking velocity of two thousand feet per second will be shivered to fragments without deeply penetrating the plate. The extreme point of the projectile, which may slightly penetrate the plate, will be found to be welded thereto by the great heat resulting from the sudden stoppage of the projectile in its flight.

Owing to the great tenacity and the heterogeneous crystalline structure of the supercarburized and hardened stratum, its tough backing, and the entire homogeneity of the plate from one surface to the other, except as to its crystalline structure, there will be no cracking off of the hardened exterior stratum and no complete piercing of the plate by the projectile. In these particulars the plate will be found to differ in a marked degree from all armor-plates heretofore known.

What is claimed as the invention is—

1. The herein-described method of producing a decrementally-hardened tenacious armor-plate, which consists in inclosing a low steel plate between a mass of non-carbonaceous material on one side and a mass of granular carbonaceous material firmly packed upon the other side contained in a compartment formed within the heating-chamber of a suitable furnace and in maintaining the said heating-chamber for a predetermined period

of time at a temperature above the melting-point of cast-iron, and in subsequently chilling said plate, whereby a stratum of steel of prescribed thickness upon the side of the plate against which said carbonaceous material has been pressed is made to acquire a heterogeneous crystalline structure and a condition of excessive hardness upon its exposed surface and a condition of gradually-diminishing hardness as the depth from said surface increases.

2. As a product of the herein-described process, the decrementally-hardened steel armor-plate herein described, consisting of a plate of tenacious steel presenting upon the side intended for receiving the impact of projectiles a stratum of prescribed thickness of ununiform crystalline structure uniformly and highly supercarburized and excessively hard at its exposed surface and less and less carburized and gradually diminishing in hardness as the depth from said surface increases.

HAYWARD A. HARVEY.

Witnesses:
A. M. JONES,
J. E. BURNS.