

July 20, 1943.

A. L. ABBOTT

2,324,808

ART OF ARMOR PLATE MANUFACTURE

Filed Jan. 22, 1940

2 Sheets-Sheet 1

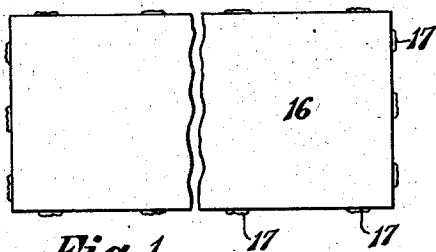


Fig. 1

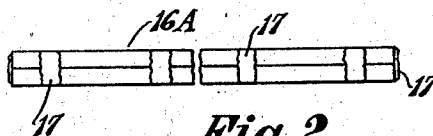


Fig. 2

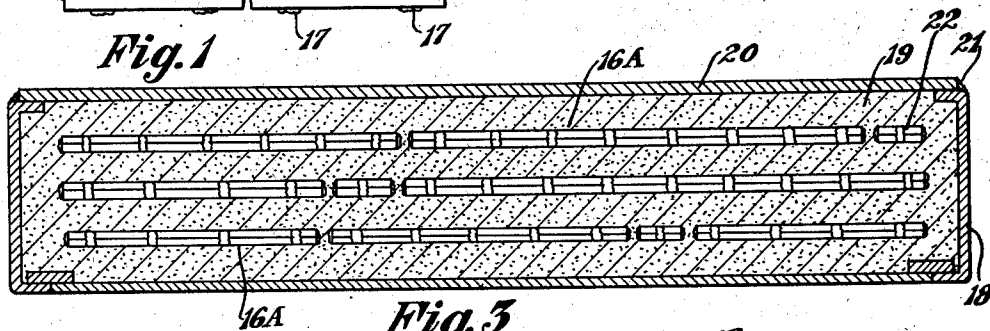


Fig. 3

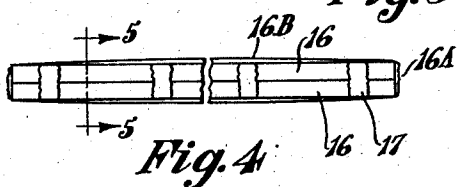


Fig. 4

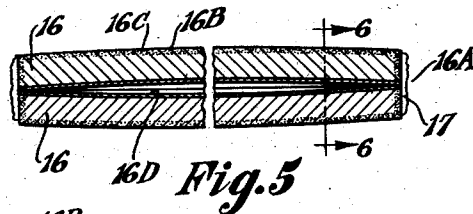


Fig. 5

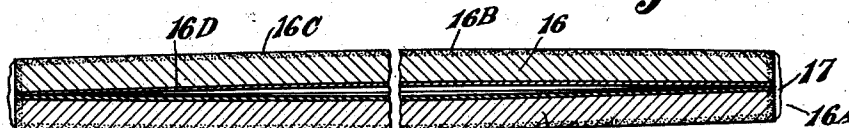


Fig. 6



Fig. 7

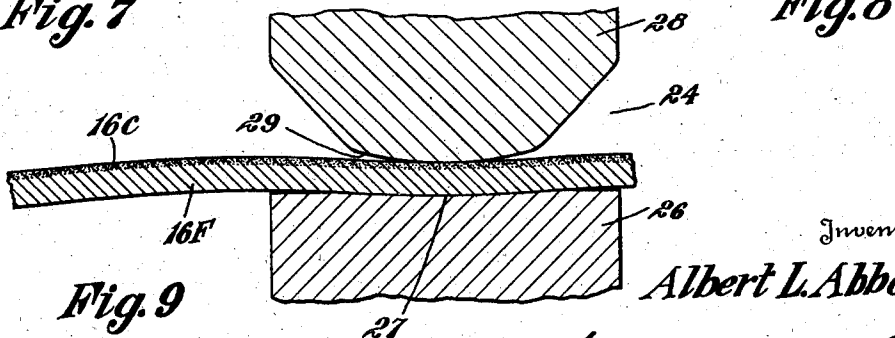


Fig. 8

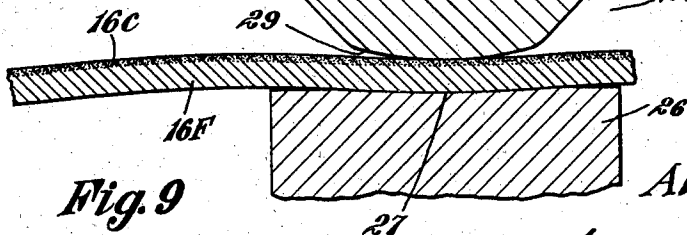


Fig. 9

Inventor.

Albert L. Abbott

By

Freese and Bishop
Attorneys

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A. L. ABBOTT

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ART OF ARMOR PLATE MANUFACTURE

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2 Sheets-Sheet 2

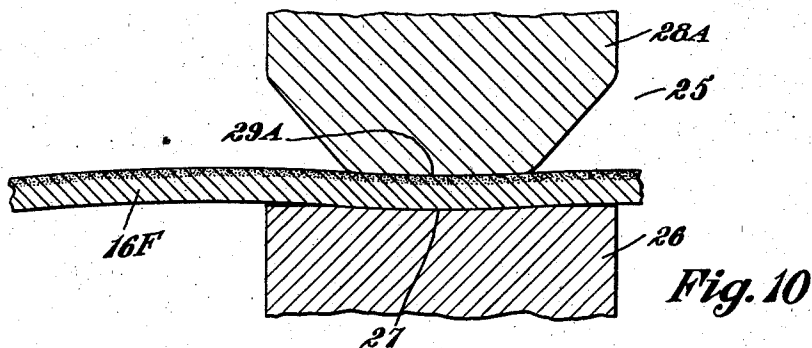


Fig. 11

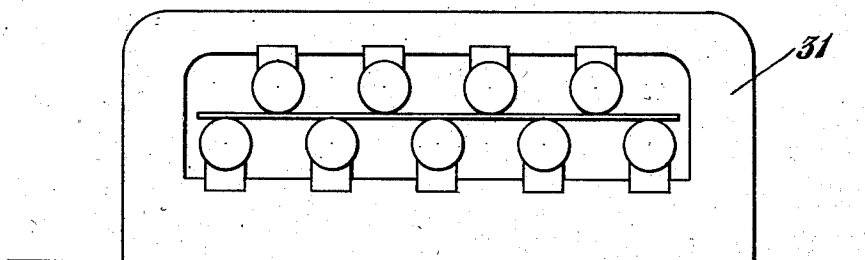


Fig. 12

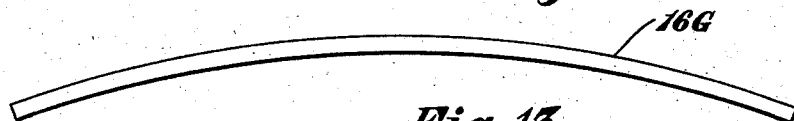


Fig. 13

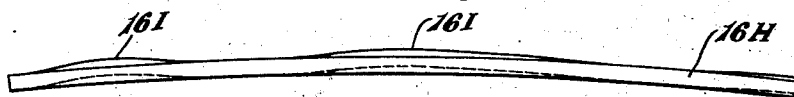


Fig. 14



Fig. 15

Inventor
Albert L. Abbott

By *Fress and Bishop*
Attorneys

UNITED STATES PATENT OFFICE

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ART OF ARMOR PLATE MANUFACTURE

Albert L. Abbott, Canton, Ohio, assignor to Diebold Safe & Lock Company, Canton, Ohio, a corporation of Ohio

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27 Claims. (Cl. 148—12)

The invention relates to steel armor plate and more particularly to thin steel armor plate, such as $\frac{1}{4}$ ", $\frac{1}{2}$ ", $\frac{3}{8}$ " and up to 1" thick steel armor plate, and to the manufacture thereof. During the last few years there has been an increasing demand for thin steel armor plate having a hard region or case at and adjacent one or the outer surface thereof merging into a softer backing or region at and adjacent the other or inner surface thereof.

Certain procedures for the manufacture of thin steel armor plate have been known. However, there has been a recent demand for thin armor plate for use in the construction of land, sea or air, offensive and defensive weapons, equipment, materials, and armament, having combined physical and ballistic properties, that, so far as I have been able to determine, could not be obtained in armor plate made by known methods.

Difficulties which characterize prior methods of making thin armor plate, such as $\frac{1}{4}$ ", $\frac{1}{2}$ ", $\frac{3}{8}$ " and up to 1" armor plate, include among others, a resultant uneven and non-uniform hard region or case, particularly at and adjacent the plate edges and hole surfaces drilled prior to carburizing; an excessive loss of material which was initially provided at and adjacent the edges of plates, then processed and then removed and scrapped, because of warpage, cracking and unevenness of case in the regions removed; the necessity of annealing plates after carburizing, and before machining and initial sizing thereof; the impossibility of straightening plates to remove warps, bends or buckles if the plates were fully quenched following heat treatment thereof to develop high ballistic properties; and the impossibility of developing high ballistic properties in the plates when using only a partial quench which enabled the plates to be subsequently straightened. One or more of these difficulties may have prevented the results of the present invention from being obtained in carrying out prior practice.

I have discovered that these difficulties may be entirely eliminated and that steel armor plate of the thinner gauges, such as $\frac{1}{4}$ ", $\frac{1}{2}$ ", $\frac{3}{8}$ " and up to 1" armor plate, can be economically, efficiently and speedily made by an entirely new and radically different manufacturing procedure, which, with respect to prior procedures, eliminates some operations, changes the character of other operations, changes the order of many operations, and utilizes uncontrollable difficulties inherent in prior procedure as procedural aids or advantages; so that the resulting thin steel armor

plate has combined physical and ballistic properties which could not be obtained by prior methods, and which exceed present day requirements.

It is therefore an object of the present invention to provide a method of making thin steel armor plate which eliminates prior art difficulties and enables the production of armor plate having ballistic properties materially in excess of those obtained in thin steel armor plate manufactured in accordance with prior practice.

It is also an object of the present invention to eliminate inner surface carburization, to eliminate undesirable warpage, to prevent cracking, to prevent uneven edge carburization, to eliminate drilled hole surface carburization, and to provide for a uniform depth of carburized region during the carburizing step in a method of making thin steel armor plate.

It is also an object of the present invention to control or minimize variations in the rate of heating or cooling of plates during the carburizing step in a method of making thin steel armor plate.

It is a further object of the present invention to eliminate an annealing operation following the carburizing step and preceding machining, drilling, cutting, shearing and sizing (and bending if required), of carburized plates in a method of making thin steel armor plate.

It is also an object of the present invention to provide a method of making thin steel armor plate, which enables a stock or reserve of carburized plates to be built up and drawn from at the stage of manufacture where machining, drilling and shaping to size in accordance with specifications occurs.

It is also an object of the present invention to provide a method of making thin steel armor plate in which a full quench following heat treatment is utilized for developing high ballistic properties.

Likewise, it is an object of the present invention to provide a method of making thin steel armor plate in which the plates are in certain instances treated prior to heat treatment so that the inherent warpage and bending which occurs during a full quenching operation, following heat treatment, may be utilized to reduce the amount of straightening required to produce flat plates.

Also it is an object of the present invention to provide an improved straightening step which enables the removal of small wrinkles, kinks or buckles in a method of making thin steel armor plate, which such small wrinkles, kinks, or buckles

could not be removed or straightened in accordance with prior practice.

Also it is an object of the present invention to provide a method of making steel armor plates incorporating some or all of the above objectives by which armor plate of the thinner gauges, such as $\frac{1}{4}$ ", $\frac{1}{2}$ ", $\frac{3}{8}$ " and up to 1" armor plate, may be manufactured having high ballistic properties.

Likewise, it is an object of the present invention to provide an improved steel armor plate product of the thinner gauges, of the order of up to 1" in thickness, having an extremely uniform depth of case; having for $\frac{1}{4}$ " plate for example, a Brinell hardness on the hard side of the order of from 500 to 550, and on the soft side of the order of from 400 to 445; having for $\frac{1}{4}$ " plate for example, a resistance to bullet penetration at striking velocities of the order of 2000 to 2100 feet per second; having for $\frac{1}{4}$ " plate a proportionately large resistance to impact; and having for heavier gauge armor plate up to 1" in thickness a comparable hardness and proportionately greater bullet penetration and impact resistances.

These and other objects may be obtained by the methods, procedures, steps, operations, and order and character thereof, hereinafter described in detail, and set forth in the appended claims, certain steps of which are diagrammatically shown in the drawings, in which:

Figure 1 is a plan view, with parts broken away, of two steel plates assembled for being carburized;

Fig. 2 is a side elevation of the plates shown in Fig. 1;

Fig. 3 is a diagrammatic sectional view of a carburizing box or pot with plates such as shown in Figs. 1 and 2 packed therein ready for carburization;

Fig. 4 is a view similar to Fig. 2, showing warpage which may occur during a certain stage of the carburization step;

Fig. 5 is an enlarged section taken on the line 5-5, Fig. 4;

Fig. 6 is an enlarged section taken on the line 6-6, Fig. 5;

Fig. 7 is an enlarged fragmentary sectional view of a plate which has been carburized and is ready for machining;

Fig. 8 is a view similar to Fig. 7, but showing the plate after machining, drilling and sizing;

Fig. 9 is a fragmentary diagrammatic view of a roughing straightening die illustrating the operation thereof;

Fig. 10 is a view similar to Fig. 9 of a finishing straightening die;

Fig. 11 is a side elevation of a completed armor plate ready for shipment;

Fig. 12 is a diagrammatic view of a stand of rolls for imparting curvature to the armor plate during the processing thereof when desired;

Fig. 13 is a side elevation of an armor plate showing curvature imparted thereto by the rolls illustrated in Fig. 12;

Fig. 14 is a view similar to Fig. 13, but showing the plate after it has been heat treated and fully quenched; and

Fig. 15 is a view showing the plate of Fig. 14 after it has been straightened.

Similar numerals refer to similar parts throughout the various figures of the drawings.

The raw material for carrying out the improved method is alloy steel plates 16 as received from the steel mill of a type commonly used in the manufacture of armor plate, and

which may contain one or more of the following alloying metals: chromium, nickel, molybdenum, vanadium, manganese. For instance, steel plates made from S. A. E. steels such as Nos. 2515, 2520, 4815 or 4820 may be used. These plates are laid off and sheared or cut generally to size in accordance with specifications. No holes are drilled at this time.

The improved method thus initially departs from prior practice because, in accordance with prior practice, some or all of the holes, required by specifications, are at this time drilled so that two matched plates can be bolted together for carrying out the carburizing step. The elimination of hole drilling at this time in accordance with the present invention, provides a number of advantages to be later referred to.

Next, a non-case or carbon resistant material commonly used in carburization, is sprayed on the side of a plate which is intended to be the soft side of a finished plate. Here again, the procedure departs from prior practice, by spraying the non-case material instead of painting it. This results in a considerable saving in time and therefore in the cost of applying the non-case, even though more non-case material may be used. Moreover, the non-case spraying procedure enables the provision of a more uniform coating, or of a heavy non-case coating, if required, in a short time.

Two matched plates 16 are then temporarily clamped together with the non-case coated faces contacting. While thus temporarily clamped, the edges of the two plates are tack welded at a number of places around the periphery thereof as indicated at 17 in the drawings.

The securing of a pair of plates together by tack welding rather than by bolting through drilled holes also provides a number of advantages to be later referred to.

Next, the clamps are removed and the pairs of plates 16A, tack welded together, are packed in a carburizing box or pot 18. In packing the plates 16A in the boxes 18, the plates are surrounded by carbonaceous material 19 of the usual character, which is high in carbon content and will liberate carbon to the plates at high temperatures.

The carburizing material, in accordance with usual practice, may be used over and over with the addition of some new material and the depth of the material 19 between plate layers when packed ordinarily ranges from $1\frac{1}{2}$ to 3 inches, depending upon the depth of case desired and the thickness of the plates.

In packing the plates 16A in the boxes 18, all edges of all plates are kept away from the sides of the box and from touching each other, as illustrated, so as to reduce as much as possible, any differential in the rate of heating and cooling of the plates and particularly the edges thereof during the carburizing step, which helps to control warpage and to facilitate machining at a later stage in the process.

Formerly, in packing the plates 16A in the boxes 18, the plate edge spacing from the box sides was not controlled, which resulted in variations in the plates due to a high differential in the rate of heating or cooling thereof.

The box 18 is then covered with a lid 20 and sealed with fire clay 21 in the usual manner and placed in a carburizing furnace wherein the temperature is raised to from 1680° F. to 1700° F. furnace temperature in about four to six hours. The plates in the boxes 18 are thus treated at the

stated temperature in the carburizing furnace for a total furnace on to furnace off time of approximately 44 to 50 hours, usually about 46 hours for $\frac{1}{4}$ " plate.

Small variations in the furnace time and temperature are determined by the depth of case desired; the hardness desired; the ballistic resistance desired; steel analysis; and grain size; and these matters are known in the art of carburizing where the small variations are ordinarily left largely up to the skill of the operator.

The sealed boxes 18 are then removed from the carburizing furnace and are permitted to slowly cool until stone cold, which may be from three to five days or even one week.

Here again the procedure departs from prior practice in which the boxes were partially cooled in the furnace and then opened while still warm and the plates permitted to cool in the air. By using the described slow cooling of the present invention, the furnace capacity is increased, although the elapsed total time for the treatment of any particular piece may be lengthened. Also, I have discovered that the particular cooling procedure, after the treatment in the carburizing furnace, renders a subsequent annealing operation, formerly required unnecessary. This annealing operation used to be required in accordance with prior practice in order to permit subsequent machining.

Referring to the previously noted omission of the initial hole drilling step of the prior art, to the previously noted omission of the prior art step of bolting a pair of plates together during carburization through such holes, and to the inclusion in the present method of a step of tack welding together a pair of imperforate plates; a number of difficulties are overcome and advantages achieved by the procedure of the present invention.

Thus, with a pair of plates bolted together, carburization may creep in along the drilled hole surfaces to the inner surface of the plate during the carburizing step, which prevents the maintenance of a uniform softer inner or backing surface or region in the plate. Likewise, the bolts frequently break during the carburizing step, which obviously allows carburization to creep in along the hole surfaces.

Moreover, if the bolt holes are too close to the edges of the plates, the plates may crack between the holes and the edges during carburization. Also, the plate edges frequently warp open away from one another, permitting carburization to creep in along the inner surface from the warped opened edges, and such warpage may also occur if any bolts break. These prior art conditions have required considerable additional metal to be provided all around at the edges, in order that warped and inner surface carburized edges can be later removed and yet leave a plate sized in accordance with specifications.

On the other hand, by welding it is assured that the plates will not break open or warp open at the edges. The welds positively hold the plates together and maintain a more intimate seal between the plate edges. This seal, together with the imperforate character of the plates during carburization, prevents inner surface carburization of the plates.

If the plates warp during carburization, the resulting configuration is as shown in a very exaggerated manner in Figs. 4, 5 and 6, wherein each of the plates 16 of the pair 16A will have an outward convexity as indicated at 16B. This

warpage tends to increase the edge seal between the plates so that it helps to prevent, rather than to cause, inner surface carburization. As a result, plates so carburized have a much more uniform depth of case on the hard side and on the edges as indicated at 16C in the drawings.

In Figs. 5 and 6, the non-case material is diagrammatically indicated at 16D; and in Fig. 3 small paired test pieces of plate 22 may be located at various regions in the box 18 for subsequent testing as to depth and character of case.

After the boxes 18 and contents thereof have cooled to be stone cold, the boxes are opened and the paired plates 16A are removed from the box. Next, the paired plates are separated by hitting the welds which are brittle and will break; and the welds are thereafter removed and the non-case surface 16D ground off.

At this point in the procedure, an annealing step was required in accordance with prior practice, but is eliminated in accordance with the present invention. The plates at this time are indicated at 16E in Figure 7 of the drawings.

The necessary holes are now drilled in the plates 16E as indicated at 23 in Fig. 8, to meet specifications; also the plates are shaped to size by machining, and the edges may be bevelled if required, as indicated at 23a, to produce the plates as shown at 16F. It is frequently unnecessary to remove the cased edges, but if the edges are bevelled, removal of the cased edges naturally results.

If it is desired or necessary that the plates be bent to meet specifications, they may be bent at this time and they may also be sheared for shaping and sizing.

As a result of this procedure, the amount of spoiled or cracked material is materially reduced and necessary machining may be readily accomplished. Moreover, machining and drilling can be most accurately done so as to insure a more accurate location of drilled holes and machined edges in the ultimate finished product. Likewise, machined edges and drilled holes are not carburized on the surfaces thereof. Accordingly, a stock of carburized plates such as indicated at 16E in Fig. 7, may be built up and drawn from at this point to fill orders for plates of desired sizes and shapes, which materially facilitates the production thereof.

The steps of the method as thus far described are used in making steel armor plate of the thinner gauges such as $\frac{1}{4}$ ", $\frac{1}{2}$ ", $\frac{3}{8}$ " and up to 1" thin plate and may be used in the manufacture of even thicker armor plate. However, from this point on, the procedure varies somewhat in accordance with the thickness of the plates being made. The succeeding treatment in accordance with the present invention, of $\frac{1}{4}$ " plate is, however, fundamentally the same as that used in the manufacture of plates of different thickness up to 1" thick plate, as will be later described.

First referring to the $\frac{1}{4}$ " plate procedure, the machined and drilled plates 16F, shown in Fig. 8, are placed in a heat treating furnace on a fire brick hearth, in which furnace the temperature of the material is raised to a point above its Ac3 point (1375° F. to 1550° F.). The plates are held at this temperature until the carbon in the case is fairly well in solution, which may be for approximately one hour, after which the plates are removed and quenched in oil maintained at a temperature of about 105° to 120° F. until the plate temperature reaches the oil temperature. The temperature of the oil has two

factors, it controls the condition of the hard side of the plate, and it also controls warpage.

I have discovered that warm oil does better work than cold oil, for there is less tendency for the plates to warp or buckle with oil at 105° to 120° F. than with colder oil. A full quench at this stage of the process enables the high ballistic properties now being demanded in thin armor plate to be obtained, along with the desired hardness of case on the hard side. After quenching, the plates are placed in a tempering or drawing bath of oil maintained at about 400° F. for thirty minutes to one hour, and are then removed and cooled.

Thereafter, the usual hardness tests are made on the hard and soft sides, which may average for example, a Brinell hardness on the hard side of 500 to 550, and on the soft side of 400 to 445.

The plates are then straightened on a hammer or power press, which may include a set of roughing dies indicated somewhat diagrammatically in Fig. 9 at 24, and a set of finishing dies indicated somewhat diagrammatically in Fig. 10 at 25.

In the roughing die 24, a bottom die 26 is used, which has a very shallow concavity 27, and a top die 28 which has a rounded nose 29. By locating the plates between the dies with any plate concavity turned downward, and operating the press to strike the plate between the dies, major convexity or curves or warps or bends may be removed, and in many cases, the plate may be completely flattened.

However, if small buckles, wrinkles or kinks occur during the quenching operation, which formerly could not be removed by any known straightening operation without cracking or breaking the plates, the roughing die 24 is first used and then the finishing die 25 is used. The finishing die has a similar bottom die 26 having a very shallow concavity 27, and a top die 28A having a generally flat nose 29A rounded substantially on the same, or a slightly less radius, as that on which the bottom die concavity is formed.

The finishing die 25 also operates, as shown in Fig. 10, upon material 16F with the concaved side down and the hard side up. However, the die surfaces 27 and 29A, due to their substantial width and substantially similar curvature, bottom on the material so that the die pressure is distributed along the entire surface of the wide nose of the top die, which may be an inch or more in width. This distributed pressure enables the small kinks or buckles or wrinkles to be pressed, squeezed or ironed out in such a manner that a flat finished plate, such as indicated at 30 in Fig. 11, results. The plates 30 are then finally resized by grinding if necessary, inspected and shipped.

Now referring to the ½" plate procedure, the machined and drilled plates 16F, such as shown in Fig. 8, are normalized by a high temperature anneal, not sufficiently long enough to spheroidize the carbon. This normalizing is accomplished by heating the plates for approximately one-half hour soaking period at approximately 1700° F. The plates are then removed from the annealing furnace and are permitted to cool in the air to approximately 600° F. The tendency during this cooling is for the plates to curve or bend while cooling with the hard side concave.

The plates are then passed for a number of passes through a stand of rolls indicated diagrammatically at 31 in Fig. 12, which roll the

plates until the hard side is substantially convex as indicated at 16G in Fig. 13. The plates are then permitted to cool with the soft side down on a cool flat surface, which imparts a permanent set to the plates with the hard side convex, as shown in Fig. 13.

The plates 16G are then placed in a heat treating furnace on a fire brick hearth and raised to a temperature above the Ac3 point (1375° F. to 1550° F.) as in the ¼" plate procedure. The plates are held at this temperature until the carbon in the case is fairly well in solution, which may be for approximately one hour and a quarter, after which the plates are removed and quenched in oil maintained at a temperature of about 105° to 120° F. until the plate temperature reaches the oil temperature. As previously stated, the temperature of the oil has two factors, that of controlling the condition of the hard side and of warpage.

The usual hardness tests are made, which may, for ½" plates for example, average a Brinell hardness on the hard side of 500 to 550, and on the soft side of 400 to 445. The plates are then straightened on a hammer or power press, using either or both of the roughing dies 24 and finishing dies 25, as previously described. Finally, the plates 30a shown in Fig. 15, are resized by grinding if necessary, inspected and shipped.

Thus, the ½" plate procedure is fundamentally the same as the ¼" plate procedure, except that the heat treating and quenching operations are preceded by a high temperature anneal and a rolling to place the plates in a condition in which the hard side is substantially convex. The subsequent heat treating after rolling results in some shrinkage on the hard side, particularly during the full quench, which cannot be prevented. The convexity imparted by the rolling operation is such that on shrinking during the full quench, the plates will not pass through a flat condition to a concave shape on the hard side.

However, the inherent effect of the full quench in causing some shrinkage on the hard side, substantially reduces the convexity imparted by the rolling operation so that the amount of straightening necessary on the straightening dies is diminished.

Fig. 14 diagrammatically illustrates, in an exaggerated manner, the condition of the plates after the full quench in which the general convexity of the hard side is quite shallow, as indicated at 16H, and in which buckles, warps or kinks are indicated in an exaggerated manner at 16I.

Thus, the high temperature anneal places the plates in the best condition for rolling. This rolling step must not be done while the plates are too hot, because the subsequent heat treatment will pull out the convexity imparted by rolling. Likewise, the rolling must not be done while the plates are too cold, or the material will crack while being rolled. The rolling of the plates, however, prior to heat treating, enables the plates to be brought to the straightening operation with the hard side slightly convex and at the same time enables a full quench to be used in order to develop high ballistic properties.

This procedure of the present invention is a radical departure from prior practice, in which the plates were only given a partial quench, were then flattened or made slightly concave on the hard side and were then permitted to cool, dur-

ing which cooling the plates reverse themselves from a concave to a slightly convex shape on the hard side, after which a straightening was performed. This prior practice procedure, however, in necessitating a partial quench followed by a roller straightening operation, prevented highest ballistic properties from being developed in the ultimate product.

The procedure in accordance with the present invention for making thicker plates such as $\frac{3}{4}$ " plates up to 1" plates is substantially the same as that for making $\frac{1}{2}$ " plates, excepting that the time for normalizing is proportionately longer depending upon the thickness of the plates, and the time of treatment in the heat treating furnace is proportionately longer depending upon the thickness of the plates.

The resulting finished plates have a hardness comparable to plates made in accordance with prior practice, but have ballistic resistances from 10 to 15 per cent higher than in any plates made in accordance with prior practice; and the resulting plates also have a much greater impact resistance.

For example, $\frac{1}{4}$ " armor plate made in accordance with the present process, under actual tests, resists bullet penetration by standard armor penetration bullets at striking velocities up to 2000 to 2100 feet per second.

Referring to the carburizing step, right and left plates are usually required, so that a matching or pairing of plates 16A can ordinarily be effected. However, if only one plate is required, or if a matching of plates is not practical, a dummy plate can be welded to the plate made in accordance with specifications, in carrying out the carburizing step.

In its broadest aspects, the invention which comprises the present improved method contemplates an entire realignment of steps, and radical changes in and omissions of steps, used in the manufacture of armor plate of the thinner gauges, which materially simplifies the manufacture of such armor plate and renders it possible to make armor plate satisfying present day requirements.

Thus, the present invention provides for overcoming the difficulties and eliminating many of the operations and consequent disadvantages resulting, involved in the prior practice of making armor plate of the thinner gauges.

In the foregoing description, certain terms have been used for brevity, clearness and understanding, but no unnecessary limitations are to be implied therefrom beyond the requirements of the prior art; because such words are utilized for descriptive purposes herein and not for the purpose of limitation, and are intended to be broadly construed.

Moreover, the invention is not limited to the production of the exact structures shown herein, because armor plate of substantially any thickness in the thinner gauges, up to 1" in thickness may be made in accordance with the described method without departing from the scope of the present invention.

Likewise, certain of the steps, such as the carburizing steps, the preparation of the plates after carburizing and before heat treatment, the preparation of the plates for heat treatment, and the straightening thereof after heat treatment, may be advantageously used in the manufacture of armor plate thicker than 1" in thickness, without departing from the scope of the present invention.

Having now described the features of the invention, the preferred steps and preferred sequence of steps used in carrying out the improved method, the advantages and results obtained by the use of the same, and the improved resulting armor plate product; the new and useful methods, method steps, operations, and products, and reasonable mechanical equivalents thereof obvious to those skilled in the art, are set forth in the appended claims.

I claim:

1. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of coating the backing side of an imperforate plate with a non-case material, covering the coated side with another imperforate plate, tack-welding the edges of said plates together, carburizing the plates, and then removing the welds and non-case material and drilling and machining the plates.

2. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of coating the backing side of plates with a non-case material, carburizing the plates in pairs with the non-case coated surfaces of the plates of each pair facing each other, maintaining the extreme contacting surfaces adjacent the edges of the plates of each pair in intimate contact during carburization, then drilling the plates, and then heat treating and straightening the plates.

3. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of carburizing the case side of imperforate plates, holding the plates at the edges so that only convex plate warpage on the hard side can occur during carburization, then drilling the plates, and then heat treating and straightening the plates.

4. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of carburizing the case sides of plates in a box in the presence of a carbonaceous material by the application of heat, maintaining a substantial thickness of carbonaceous material between the box walls and all plate edges and surfaces to control differentials in the rate of heating and cooling and resultant warpage of the plates throughout during carburization, then slowly cooling the plates, then after cooling drilling the plates without annealing the plates, and then heat treating and straightening the plates.

5. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of carburizing the case sides of imperforate plates in a sealed box in the presence of a carbonaceous material by heating the sealed box in a furnace, slowly cooling the sealed boxes until the plates are stone cold, then after cooling, drilling and machining the plates to specified shape without annealing the plates, and then heat treating and straightening the plates.

6. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of carburizing the case sides of imperforate plate blanks in pairs in a sealed box in the presence of a carbonaceous

material by heating the sealed box in a furnace, slowly cooling the paired plate blanks in the sealed box until stone cold; then after cooling, shearing, drilling, and machining the blanks to form plates of specified shape from said plate blank without annealing the blanks; and then heat treating and straightening the plates.

7. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of coating the backing side of an imperforate plate with a non-case material, covering the coated side with another imperforate plate, tack welding the edges of said plates together, carburizing the plates in a sealed box in the presence of a carbonaceous material by heating the sealed box in a furnace, slowly cooling the plates in the sealed box until stone cold, maintaining a substantial thickness of carbonaceous material between the box walls and all plate edges and surfaces to control differentials in the rate of heating and cooling and resultant warpage of the plates throughout during heating and cooling, then removing the welds and non-case material and drilling and machining the plates, and then heat treating and straightening the plates.

8. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of spraying a non-case material on the backing side of imperforate plates, covering the backing side of one plate with another to form a pair, tack welding the edges of said plates together to hold and maintain the extreme contacting surfaces adjacent the edges of the plates of each pair in intimate contact so that only convex plate warpage on the hard side can occur during subsequent carburization, carburizing the plates in a sealed box in the presence of a carbonaceous material by heating the sealed box in a furnace, slowly cooling the plates in the sealed box until stone cold, maintaining a substantial thickness of carbonaceous material between the box walls and all plate edges and surfaces to control differentials in the rate of heating and cooling and resultant warpage of the plates throughout during heating and cooling, then removing the welds and non-case material and drilling and machining the plates, and then heat treating and straightening the plates.

9. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of spraying a non-case material on the backing side of imperforate plates; temporarily clamping two plates together with the non-case covered sides contacting to form a pair; tack welding the edges of said paired plates together to hold and maintain the extreme contacting surfaces adjacent the edges of the plates of each pair in intimate contact so that only convex plate warpage on the hard side can occur during subsequent carburization; removing the clamps; packing tack welded paired plates in a box in carbonaceous material with a substantial thickness of carbonaceous material between the box walls and all plate edges and surfaces to control differentials in the rate of heating and cooling and resultant warpage of the plates throughout during subsequent heating and cooling; sealing the box; heating the sealed box in a furnace to treat the plates for from about forty-four to fifty hours at about 1680° to 1700° F.; removing the sealed box from the furnace and slowly cooling the plates in the sealed box for from four

days to one week until stone cold; removing the paired plates from the box; removing the welds and non-case material from the plates; drilling and machining the plates to specified shape; and then heat treating and straightening the plates.

10. In the manufacture of steel armor plate of the thinner gauges of the order up to 1" in thickness having a hard case side and a softer backing side, the steps of carburizing the case side of a plate, then heat treating the plate in a heat treating furnace until the carbon in the case side is fairly well in solution, then fully quenching the plate in oil to an oil temperature of about 105° to 120° F., and then straightening the plate.

11. In the manufacture of steel armor plate less than 1/2" thick having a hard case side and a softer backing side, the steps of carburizing the case side of a plate, then heat treating the plate in a heat treating furnace until the carbon in the case side is fairly well in solution, then fully quenching the plate in oil to an oil temperature of about 105° F. to 120° F., then tempering the plate, and then straightening the plate.

12. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of carburizing the case side of a plate, then heat treating the plate in a heat treating furnace for one hour or more at about 1375° to 1550° F. until the carbon in the case side is fairly well in solution, then fully quenching the plate in oil to an oil temperature of about 105° to 120° F., and then straightening the plate.

13. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of carburizing the case side of a plate, then heating the plate, then fully quenching the plate in oil to an oil temperature of about 105° F. to 120° F., and then straightening the plate by a multiplicity of blows between dies having slightly curved work contacting faces of substantial width and length exerting a distributed squeezing pressure on the work.

14. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of carburizing the case side of a plate, then heating the plate, then fully quenching the plate in oil to an oil temperature of about 105° F. to 120° F., then removing major warpage resulting from quenching by subjecting the plate to a multiplicity of blows between dies having curved work contacting faces of substantially different curvature, and then removing smaller kinks and wrinkles by subjecting the plate to a multiplicity of blows between dies having slightly curved work contacting faces of substantially the same curvature and of substantial width and length exerting a distributed squeezing pressure on the work.

15. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of carburizing the case side of a plate, then normalizing the plate by a high temperature anneal, then cooling the plate in air to approximately 600° F., then rolling the plate until the case side is convex, then heating the plate, then fully quenching the plate, and then straightening the plate.

16. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1"

in thickness having a hard case side and a softer backing side, the steps of carburizing the case side of a plate, then heating the plate and soaking it at about 1700° F. for up to about one hour to normalize the plate, then cooling the plate in air to approximately 600° F., then rolling the plate until the case side is convex, then heating the plate until the carbon in the case side is fairly well in solution, then fully quenching the plate in oil to an oil temperature of about 105° to 120° F., and then straightening the plate.

17. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of carburizing the case side of a plate, then normalizing the plate by a high temperature anneal, then while the plate still retains a substantial portion of the annealing heat rolling the plate until the case side has such convexity that shrinkage of the case side during a subsequent full quench will not produce concavity in the case side, then heating the plate, then fully quenching the plate, and then straightening the plate.

18. In the manufacture of steel armor plate of the thinner gauges of the order of ½" to 1" in thickness having a hard case side and a softer backing side, the steps of carburizing the case side of a plate, then normalizing the plate by a high temperature anneal, then air cooling the plate to about 600° F., then rolling the plate to impart convexity to the case side thereof, then heat treating the plate in a heat treating furnace for one hour or more at about 1375° to 1550° F. until the carbon in the case is fairly well in solution, then fully quenching the plate in oil to an oil temperature of about 105° to 120° F., and then straightening the plate.

19. In the manufacture of steel armor plate less than ½" thick having a hard case side and a softer backing side, the steps of carburizing the case side of a plate, then heating the plate in a heat treating furnace for approximately one to one and one-quarter hours at about 1375° to 1550° F. until the carbon in the case side is fairly well in solution, then fully quenching the plate in oil to an oil temperature of about 105° to 120° F., then tempering the plate in an oil bath at about 400° F. for from one-half to one hour, then cooling the plate, and then straightening the plate.

20. In the manufacture of steel armor plate from about ½" to less than ¾" thick having a hard case side and a softer backing side, the steps of carburizing the case side of a plate, then heating the plate and soaking it at about 1700° F. for from about thirty to about forty minutes to normalize the plate, then cooling the plate in air to approximately 600° F., then rolling the plate until the case side is convex, then heating the plate in a heat treating furnace for approximately one and one-quarter to one and one-half hours at about 1375° to 1550° F. until the carbon in the case side is fairly well in solution, then fully quenching the plate in oil to an oil temperature of about 105° to 120° F., and then straightening the plate.

21. In the manufacture of steel armor plate from about ¾" to less than 1" thick having a hard case side and a softer backing side, the steps of carburizing the case side of the plate, then heating the plate and soaking it at about 1700° F. for from about forty to about sixty minutes to normalize the plate, then cooling the plate in air to approximately 600° F., then rolling

the plate until the case side is convex, then heating the plate in a heat treating furnace for approximately one and one-half to two hours at about 1375° to 1550° F. until the carbon in the case side is fairly well in solution, then fully quenching the plate in oil to an oil temperature of about 105° to 120° F., and then straightening the plate.

22. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of spraying a non-case material on the backing side of an imperforate plate, covering the backing side with another imperforate plate, tack welding the edges of said plates together, carburizing the plates, removing the welds and non-case material, drilling and machining the plates, heat treating the plates in a heat treating furnace until the carbon in the case side is fairly well in solution, then fully quenching the plates in oil to an oil temperature of about 105° to 120° F., and then straightening the plates.

23. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of spraying a non-case material on the backing side of an imperforate plate, covering the backing side with another imperforate plate, tack welding the edges of said plates together, carburizing the plates, removing the welds and non-case material, drilling and machining the plates, normalizing the plates by a high temperature anneal, then cooling the plates in air to approximately 600° F., then rolling the plates until the case side is convex, then heating the plates, then fully quenching the plates, and then straightening the plates.

24. In the manufacture of steel armor plate less than ½" thick having a hard case side and a softer backing side, the steps of coating the backing side of an imperforate plate with a non-case material, covering the coated side with another imperforate plate, tack welding the edges of said plates together, carburizing the plates in a sealed box in the presence of a carbonaceous material by heating the sealed box in a furnace, slowly cooling the plates in the sealed box until stone cold, maintaining a substantial thickness of carbonaceous material between the box walls at all plate edges and surfaces to control differentials in the rate of heating and cooling and resultant warpage of the plates throughout during heating and cooling, removing the welds and non-case material, drilling and machining the plates, then heat treating the plates in a heat treating furnace until the carbon in the case side is fairly well in solution, then fully quenching the plates in oil to an oil temperature of about 105° to 120° F., then tempering the plates, and then straightening the plates.

25. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of coating the backing side of an imperforate plate with a non-case material, covering the coated side with another imperforate plate, tack welding the edges of said plates together, carburizing the plates in a sealed box in the presence of a carbonaceous material by heating the sealed box in a furnace, slowly cooling the plates in the sealed box until stone cold, maintaining a substantial thickness of carbonaceous material between the box walls at all plate edges and surfaces to control differentials in the rate of heating and cooling and

resultant warpage of the plates throughout during heating and cooling, removing the welds and non-case material, drilling and machining the plates, then normalizing the plates by a high temperature anneal, then while the plates still retain a substantial portion of the annealing heat rolling the plates until the case side has such convexity that shrinkage of the case side during a subsequent full quench will not produce concavity in the case side, then heating the plates, then fully quenching the plates, and then straightening the plates.

26. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of carburizing the case side of a plate and slowly cooling the plate, then after cooling forming holes through the car-

burized part of the plate and machining the plate to specified shape without annealing the plate, and then heat treating and straightening the plate.

5 27. In the manufacture of steel armor plate of the thinner gauges of the order of up to 1" in thickness having a hard case side and a softer backing side, the steps of spraying a non-case material on the backing side of a plate, carburizing the case side of the plate and slowly cooling the plate; then after cooling removing the non-case material, forming holes through the carburized part of the plate, and machining the plate to specified shape all without annealing the plate; and then heat treating and straightening the plate.

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ALBERT L. ABBOTT.