Dec. 2, 1952 F. S. DENNEEN ET AL 2,620,433

COIL FOR DIFFERENTIAL HEAT-TREATMENT

Original Filed June 1, 1942 2 SHEETS—SHEET 1

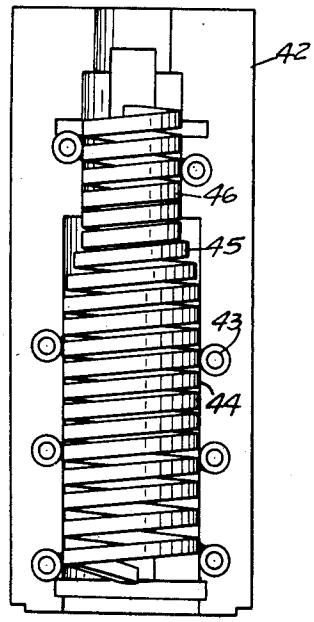


Fig. 1

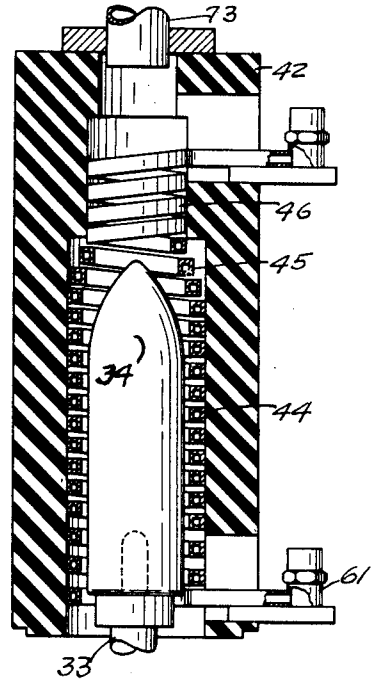


Fig. 2

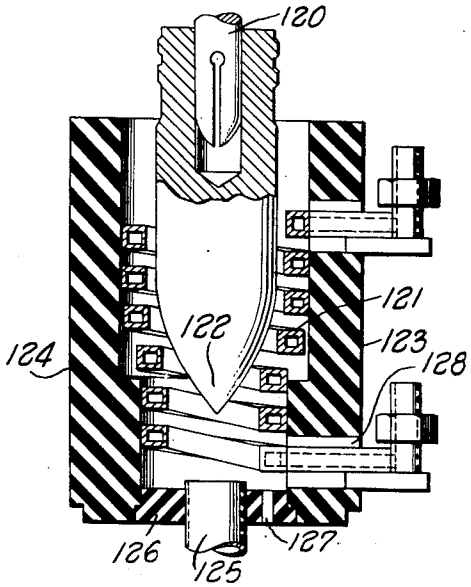


Fig. 6

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COIL FOR DIFFERENTIAL HEAT-TREATMENT

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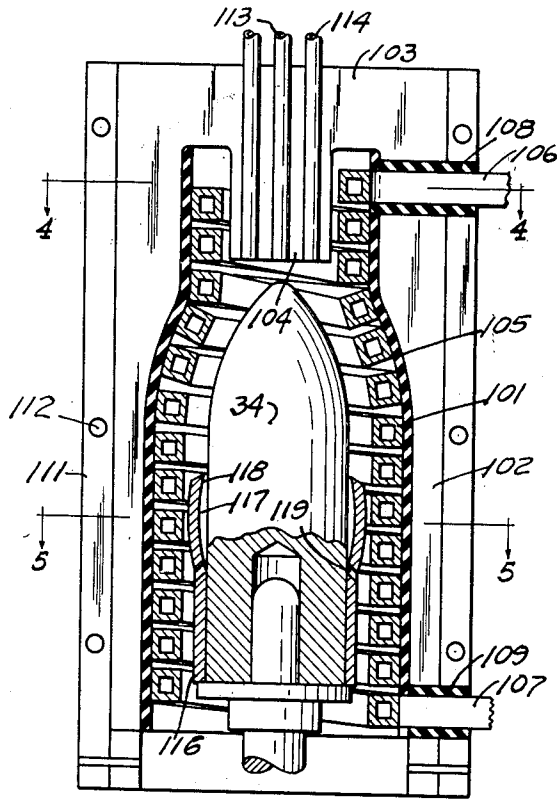


Fig. 3

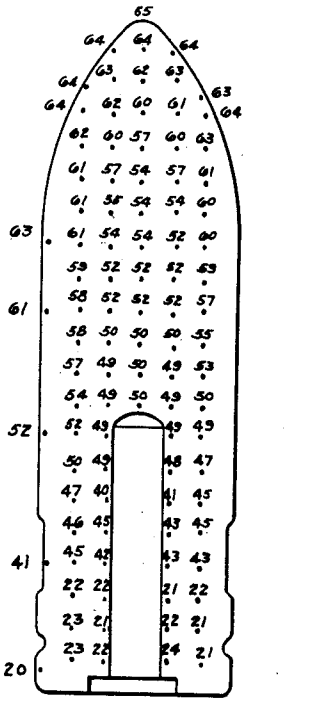


Fig. 7

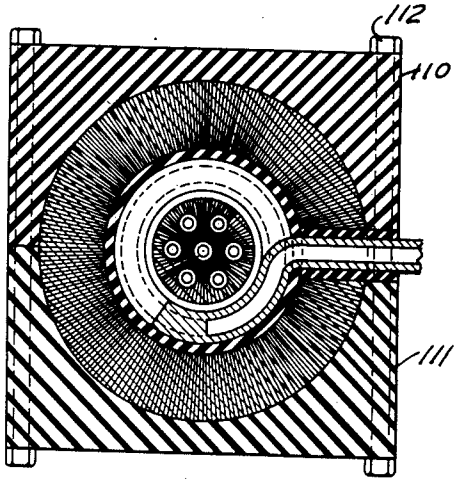


Fig. 4

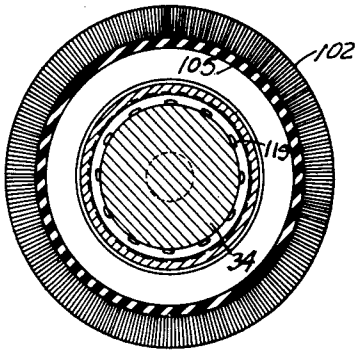


Fig. 5

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COIL FOR DIFFERENTIAL HEAT-TREATMENT

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Original application June 1, 1942, Serial No. 445,533. Divided and this application October 28, 1947, Serial No. 782,546

4 Claims. (Cl. 219—47)

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The present invention relates as indicated to apparatus for the heat treating of metallic articles. It is directed chiefly to mass production of hardened articles, and is applied principally to such articles as projectiles. This application is a division of our copending patent application Serial Number 445,533 filed June 1, 1942, Patent No. 2,430,005 dated November 4, 1947.

Pieces differing as to material and form as well as size require different heating to obtain equivalent results. Similarly the material, form and size affect the results of quenching. It is desirable in some cases that heat treating apparatus be readily adaptable to being changed over in part without being changed over in whole, i. e., it may be desirable to change the size of one heating station without changing any of the others and at the same time it should be possible to change the quenching rate without changing either the inductor or the rate of heating. The present apparatus makes possible the accurate duplication of parts regardless of size or form. This invention is particularly adapted to the mass production of hardened articles such as projectiles, particularly armor piercing shells or shot. In articles of this class it is generally required that hardness shall vary from one part to another of the article according to a predetermined pattern, that this variation of hardness shall be accurate and that the operation of hardening shall be accomplished rapidly and economically, both in regard to space employed and power and labor consumed.

In the hardening of a projectile such as an armor piercing shot, the point of the shot must be sufficiently hard so as not to flatten unduly when it strikes the armor plate. The shot must possess suitable physical qualities to be capable of being fired through the plate and without shattering at the initial impact.

In many cases it is desirable that the base of the shot be soft or in a substantially annealed condition in order to satisfactorily pierce the armor plate. Shot with fully hardened bases have a tendency to break apart or shatter at the base when fired into armor plate, while similar shot with softer or annealed bases fired under exactly the same conditions will pass through the armor plate without breaking apart. By leaving the base unhardened or by drawing it after hardening, it is possible to cut the band groove, drill and perform other machining operations on the base of the shot subsequent to the hardening operation. It is important that the hardness of the shot be properly graduated

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from the nose back toward the base, and from the external surface into the center of the body to insure the best results under firing test. It is well known that under firing tests, a properly heat treated shot will cleanly pierce through a piece of armor plate when traveling at a lower velocity at the instant of impact than would an improperly heat treated shot. Properly heat treated shot, therefore, is effective at a greater range or may be effectively fired at a lower muzzle velocity.

Heretofore articles of this kind have been heated entirely through to produce required hardness and as a result quenching strains are set up which cause incipient fractures and result in the projectile being broken partly through even before striking the armor plate and thus upon impact, the projectile breaks or even shatters into small pieces before penetration can occur.

The present method and apparatus have been developed so that such fractures can be avoided. The projectile can be made of material which will give a strong, tough core not susceptible to fracture, and at the same time the outer part can be treated to provide a high degree of hardness to insure the projectile against excessive flattening or other deformation or breakage upon impact with hardened armor or other material.

To accomplish the above desired results we have found it necessary to develop inductors of new form, and to arrange these inductors in new combinations and to provide a new method of quenching the articles after the same have been heated.

In the manufacture of shot in which there is a band groove near the base and a recess within the base, a serious difficulty is frequently met where the entire body of the shot is hardened, because of a tendency for cracks to form at the band groove, these frequently leading into the base recess.

One object of this invention, therefore, has been to provide apparatus which can be readily changed over from one form to another so as to heat treat articles of various forms and sizes. A further object has been to provide means to distribute heating along a surface zone of an article in accordance with desired results. A still further object has been to provide means for concentrating the quenching effect in desired locations. Another object has been to provide a compact device readily accessible and one which does not require highly

skilled labor for its operation. Another object has been to provide a method of hardening which is adaptable to various types and forms of articles and which provides for varying the results according to prescribed requirements. A still further object has been to provide mechanism adapted to harden such parts of a projectile as are required to be hard and to harden those parts sufficiently to provide desired armor piercing ability without harmful effects to the hardness already provided in other parts. Another object is to provide means and method to produce a desired change in hardness from one part of the article to another. A still further object is to provide a projectile having an extremely hard point, a tough core and a relatively soft base section. Other objects will become apparent from the following description.

To the accomplishment of the foregoing and related ends said invention consists of the means and method hereinafter described together with the article produced thereby, all of which are particularly pointed out in the claims. The annexed drawings and following description set forth in detail certain means and one mode of carrying out the invention and include one form of the product produced thereby. Numerous other modifications may be adapted without departing from the scope of the invention. The phraseology employed is for the purpose of explanation and not for limitations, the claims hereto appended point out those parts of the invention which are regarded as novel.

In said annexed drawings:

Fig. 1 is an elevation of the coil employed as an inductor.

Fig. 2 is an elevation of one form of article to be heat treated with a part of the inductor and supporting mechanism surrounding it shown in section.

Fig. 3 is an elevation partly in section showing a modification of the apparatus.

Fig. 4 is a section at 4—4 of Fig. 3.

Fig. 5 is a section at 5—5 of Fig. 3.

Fig. 6 is a section showing means for heating and quenching the front end of the projectile.

Fig. 7 is a section of a projectile taken on a longitudinal median plane and showing one desired distribution of hardness, cross hatching being omitted for clarity.

Referring now to the apparatus illustrated particularly in Figs. 1 and 2 of the drawings, there is shown an induction coil construction embodying the present invention which is particularly adapted for use with the apparatus shown in the aforesaid U. S. Patent 2,430,005. In the form shown, the projectile 34 is carried by a support 33 forming part of said apparatus. The inductor assembly comprises complementary insulating enclosure members such as 42 between which each inductor is securely clamped by bolts 43 as shown in Figs. 1 and 2. These members 42 are made of heat resisting electric insulation such as Transite, a Portland cement-asbestos combination, and serve as heat insulation and as means for preventing the inductors from coming into current conducting contact with surrounding metallic parts. The inductors are formed to correspond in shape generally with the article to be heat treated. For the article herein illustrated, each inductor is wound from rectangular copper tubing into coils forming a substantially cylindrical helix 44, which helix is joined by a somewhat conical section of coils 45 to another group of coils 46 in the form of a smaller cylindrical helix lying thereabove to provide a continuous conductor through which all the inducing current passes. The tapered or conical portion and the small cylindrical part of the inductor lying adjacent to the point or piercing end of the projectile causes a highly concentrated flux field in and adjacent to this point which heats the piercing end of the projectile more rapidly than other parts, quickly bringing it to hardening temperature.

Current usually at high frequency is supplied to the inductors as by bus bars, which are connected by suitable conductors to a transformer or other suitable source of current.

Since considerable energy is supplied to the inductors, their temperatures will rise at times to harmful proportions unless cooling means is provided. This is accomplished by tubes connected to the coils and to the connecting conductors to permit cooling water to flow therethrough. The hollow coils are usually of rectangular form as shown, to give better electrical performance and to provide a construction more compact than would otherwise be possible.

Since certain machining and assembly operations are sometimes desirable or necessary in the base after heat treatment, it may be required that this end be left relatively soft. This is accomplished in part by arranging the inductor so that the lower coil of section 44, Figs. 1 and 2, does not extend materially below this lower end and in some cases not even down to that end. The heating in this end therefore is much less than in the upper end where inductor section 46 extends considerably beyond the point of the projectile. The fact that the quenching rate in the lower portion of the projectile is much less due to a less vigorous action of the quenching fluid and due to the quenching fluid having become somewhat heated by passing over the heated point before reaching the base further aids in keeping the bases soft.

Further means for controlling the distribution of hardness is illustrated in Figs. 3, 4 and 5. In this modification the inductor 101 is of a form similar to that shown in Figs. 1 and 2, but is substantially surrounded by a laminated enclosure arranged to serve as a magnetic core or circuit of low reluctance. The laminations are shown arranged radially, but may be disposed in other ways. The laminations when assembled form an enclosing structure for the inductor which conforms to the outer shape of the inductor and in addition, has a core section 104 which projects down inside the upper end of the inductor. The laminated structure has an insulated lining 105 to separate the inductor from the core. The terminals 106 and 107 of the inductor are enclosed by insulating bushings 108 and 109 and extend through passages in an outer wall of the core. The entire structure is enclosed and supported by a pair of complementary insulating blocks 110 and 111 bored out to receive the cylindrical core, the blocks being held in assembled relation with the core and with each other by means of bolts such as 112.

By virtue of the core and the form of the inductor, a high concentration of heating flux in the article 34 is provided, particularly in its upper or piercing end, rapidly heating not only the surface zone but a selected portion of the interior of the projectile at that end to hardening temperature. Quenching is accomplished by projecting water or other fluid through passages provided by a group of tubes usually comprising

a central tube 113 and surrounding tubes 114 passing through the inwardly projecting core part of the lamination assembly at 104. The center tube 113 is usually somewhat larger than the surrounding tubes to deliver more quenching fluid onto the point of the projectile. Also this center tube is so connected to the source of fluid that it is under higher pressure than the pressure applied to the surrounding tubes. By controlling the size and arrangement of the tubes and the pressures employed, an accurate control of the quenching rate is provided in the point of the projectile. The timing of the quenching is so regulated that fluid is delivered from one or more of the tubes before fluid is delivered from others, further control of the quenching being accomplished by supplying the different tubes with fluid at different temperatures.

As a further means for controlling heating and quenching to reduce hardness in the base portion of the projectile, the tubular shield 116, which is of such size as to fit closely over this base portion, is applied thereto as shown most clearly in Fig. 3. When this shield is made of metal, a large part of induced current which otherwise would flow in and heat the surface zone of the projectile flows in the shield thus reducing the heating in the projectile to a very small amount. This shield also prevents more than a very small amount of quenching fluid from coming in contact with surfaces of the base part of the projectile and thus controls the quenching as well as the heating.

A limited amount of quenching is usually desired along the central part of the cylindrical wall of the projectile. To accomplish this limited quenching the shield 116 is enlarged in this region to provide an annular space 117 for the passage of a small amount of the quenching fluid. The upper annular edge of the shield is formed as indicated at 118 to serve as means for deflecting a desired amount of the fluid and to limit the amount of fluid which is permitted to enter space 117. Passages 119 serve as means for controlling the rate of escape of the quenching fluid.

From the above description it will be seen that the exterior laminated magnetic member in combination with the type and form of inductor described provides an efficient means for rapidly heating the upper or piercing end of the projectile to hardening temperature, that the axially disposed quench tubes provide an efficient and easily controlled quenching apparatus and that the shield 116 serves as a complete means for not only controlling heating but quenching in the surface zones of the central and base parts of the projectile and that by changing from one shield to another the surface zone can be varied as desired as to its shape, depth and degree of hardness.

In some instances it is desirable to harden the piercing end of the projectile only, leaving the remainder in its original soft or annealed condition. Our method is adapted to accomplish this hardening and in such instances the inductor is usually formed and assembled as shown in Fig. 6. In this illustration the inductor is substantially the same as the upper part of the inductor shown in Fig. 2, but is shown inverted. This type of inductor is adapted for use either upright or inverted as shown. The heating is substantially the same in either position but different quenching effects are accomplished. In the inverted position the shot is held by a suitable split plug such as 120 or other means engaging the tracer charge recess or other part of the base of the

shot. The inductor 121 which encloses the lower or piercing end 122 of the shot is carried by complementary supports 123 and 124. Quenching is accomplished by projecting quenching fluid upwardly from nozzle 125 against the end of the shot. By regulating the flow of the quenching fluid, the rate of quenching is easily controlled, not only of the point of the shot but of the parts extending toward the upper end or base of the shot, the rate of flow of quenching fluid regulating the rate at which heat is removed from the intermediate parts lying between the point and the base. By providing the closure disc 126 through which nozzle 125 projects and by selecting or regulating suitable escape openings such as 127 and 128, the quenching fluid is caused to rise around the shot at a desired rate and to substantially simulate quenching by dipping the end of the shot into a vigorously agitated quenching bath, such quenching having been found particularly advantageous in hardening the cutting or piercing ends of such articles as chisels, punches, bits and a wide variety of articles to which this apparatus is as well adapted as to the hardening of the shot illustrated.

In some cases the apparatus and method described in connection with Fig. 6 are used to advantage where the piece is heated to substantially its entire length, in which cases the heating coils are made to extend as far along the piece as needed to obtain the desired heating.

While the drawings show generally uniform coil spacing, there are often conditions when it is desirable to space the coils non-uniformly in order to produce the desired heating and to produce spacing between the coils for the flow of quenching medium. Such increased spacing is indicated in the coils extending around the lower end of the projectile illustrated in Fig. 2.

Fig. 7 shows a section through a typical projectile which has been hardened by our process and apparatus. The cross hatching has been omitted to permit the numerals indicating the hardness on the Rockwell C scale to be more easily read. From this it will be seen that the point possesses a maximum hardness of 65 and that the outer surface adjacent thereto is of the order of 64 and that the degree of surface hardness recedes gradually toward the base of the projectile not dropping below 60 until a point nearly half way to the base had been reached, from which point the hardness drops rapidly to about 40 a short distance from the base and then drops still more rapidly to about 20 in the immediate vicinity of the base. It will also be observed that the hardness of the interior parts not only decreases in passing from the point toward the base, but that this decrease is more uniform than the decrease of surface hardness which provides for more ductility and more resistance to fracture from impact than would be the case if extremely high hardness were provided in the interior regions near and at a short distance from the point. The soft metal at and near the base facilitates assembling operations.

The projectile from which the section shown in Fig. 7 and above described, was cut, was made from steel of S. A. E. specification #5045A and hardened in apparatus of the type shown in Figs. 1 and 2 and subsequently differentially drawn. Further widely varied but controlled results can be obtained by the use of our apparatus and methods as above set forth.

One of the chief advantages of our apparatus

and process is the exact duplication of parts. When the material from which the projectiles are made is uniform chemically and physically each of the hardened projectiles is an exact duplicate of the one which preceded it. This is accomplished by using the same amount of power and at the same frequency for each piece and heating and quenching under like conditions and for the same intervals of time. The application of the heating and quenching is timed accurately to a small portion of a second and the operation of switches and valves is automatic, being operated by time controlled solenoids.

From the above it will be observed that the projectile produced by our method possesses ability to penetrate hard and heavy armor and to pass through such armor substantially intact and to accomplish such penetration at a velocity much below that necessary for the penetration of projectiles produced by the usual methods which gives the projectile a much greater effective range.

Other modes of applying the principle of our invention may be employed instead of the ones explained, change being made as regards the means herein disclosed, as regards the method employed, and as regards the article produced, provided those stated by any of the following claims or their equivalents be employed.

We therefore particularly point out and distinctly claim as our invention:

1. Apparatus for differentially hardening an elongated, contoured, quench-hardenable article of manufacture with the hardening varying differentially from one end thereof, comprising, in combination, a helical coil adapted to surround said article and having a shape substantially corresponding to the shape of said article and having an end extending beyond the end of the article to be hardened.

2. Apparatus for quench hardening cylindrical articles of manufacture having a tapered end with a hardness varying from a maximum adjacent the tapered end to a minimum toward the other end, said apparatus including, in combination, a multiturn helical high-frequency induction coil adapted to surround said article, said coil having an inner diameter varying in direct relation to the outer diameter of the

article and having at least one turn extending beyond the tapered end of said article whereby to provide a differential heating varying from a maximum adjacent the tapered end.

3. Apparatus for heating an elongated quench-hardenable article of manufacture having a generally cylindrical shape, tapering generally to a point at one end, comprising a multiturn helical coil having generally equispaced turns, said coil coaxially surrounding said article when in heating position and at one end having a decreasing diameter to directly conform to the decreasing tapered end of the article, said coil including at least one turn of reduced diameter axially aligned with said article and positioned beyond the pointed end thereof.

4. Apparatus for heating generally cylindrical articles of manufacture having a tapered end comprising a multiturn helical high-frequency induction coil coaxially disposed around said article when in heating position, said coil having an inner diameter varying in direct relationship to the outer diameter of said article and having at least one turn of small diameter extending beyond the tapered end of said article whereby to provide a differential heating varying from a maximum adjacent the tapered end.

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