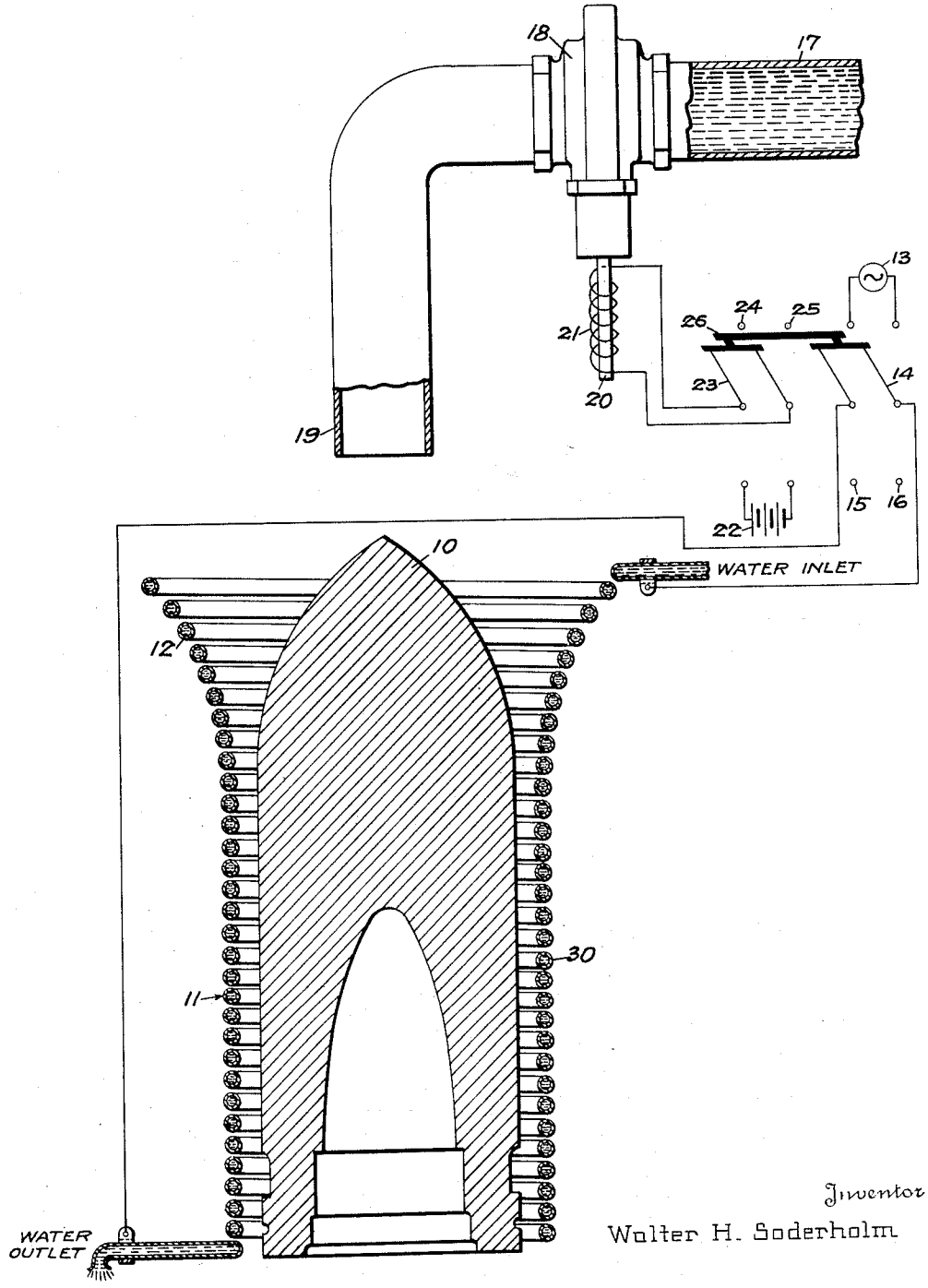
Dec. 1, 1942. W. H. SODERHOLM 2,303,408

HEAT TREATMENT OF PROJECTILES

Filed July 16, 1941



Inventor

Walter H. Soderholm

By Geo. J. Kiessnich & J. H. Church

Attorneys

Patented Dec. 1, 1942 2,303,408

UNITED STATES PATENT OFFICE

2,303,408

HEAT TREATMENT OF PROJECTILES

Walter H. Soderholm, United States Army,
Syracuse, N. Y.

Application July 16, 1941, Serial No. 402,680

4 Claims. (Cl. 148—21)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment to me of any royalty thereon.

My invention relates to the heat treatment of metals and to the production of a metallic body which is gradated in hardness or which is commonly referred to as zone hardened.

An object of an embodiment of my invention is to provide an armor piercing projectile having the proper gradation of hardness from the point and outer skin surface to a tough core.

Another object of my invention is to provide a quick inexpensive method for producing a gradation of hardness in a metal especially in an armor piercing projectile.

Another object of my invention is to provide a method and apparatus for quickly heating and quenching a metallic body so that proper gradation of hardness exists throughout the body.

The nature and further objects of my invention will appear from the following description and accompanying drawing.

It is known that various methods have been used to produce an armor piercing projectile gradated in hardness. Those prior methods, as exemplified in U. S. Patent 1,381,633, Hadfield et al., issued June 14, 1921, require a relatively long time and involve a great deal of apparatus with the result that the manufacture of armor piercing shells gradated in hardness has been an expensive undertaking. Also, most all of the prior methods involved more than one heat treatment operation with the result that the grain size of the shell material was unduly large; it is now known that by controlling grain growth in a metal its hardness can be controlled and the smaller the amount of grain growth the harder the material is. The prior art methods involved prolonged and numerous heating operations during which there was considerable grain growth and a related decrease from the optimum material hardness. Grain growth in carbon steels is pronounced at the hardening temperature and accordingly alloys which serve as inhibitors to grain growth have found extensive application in the manufacture of armor piercing projectiles. Maintaining a metal at its hardening temperature for an appreciable time results in considerable grain growth and a relatively small degree of hardness after the metal is subsequently quenched. If grain growth in carbon steels could be substantially prevented during the heat treatment operation a hard steel would be obtained and expensive alloys would no longer be necessary in the manufacture of armor piercing projectiles.

In order to substantially prevent grain growth it is necessary to heat the material to the hardening temperature in the shortest possible time and then quench the material very quickly; this is accomplished by my apparatus. In order to produce a projectile gradated in hardness it is practically necessary that there be differential or zone heating if substantial grain growth is to be prevented; in the prior art the interior of the shell was heated, due to conduction, by heat supplied to the external surface of the shell and this process of course required time for the interior portions of the shell to be heated during which there was substantial grain growth in the outer shell material. In this embodiment of my invention differential heating is accomplished by eddy currents and to a smaller extent by the hysteresis losses in the iron.

In many of the prior art arrangements gradated or zone hardening was accomplished in two or more steps, i. e., initially the shell was hardened uniformly and then by one or more steps the shell was again heated and portions thereof softened so that the tip and outer surfaces of the shell would have a greater hardness than the inner core; this method requires many heat treatment operations and of course the opportunity for grain growth in the material is enhanced. In the embodiment of my invention there is but one heating operation and one quenching operation so that there is not much opportunity for grain growth.

Referring to the drawing, in this embodiment of my invention the armor piercing projectile **10** made of pure carbon steel or carbon steel mixed with another metal is centrally disposed in a high frequency coil or modified solenoid **11** which has an arcuately flared section **12** disposed adjacent to the tip or ogival head of the projectile and a cylindrical section **30** disposed adjacent to the cylindrical portion of the shell. High frequency currents are circulated through the coil or modified solenoid **11** and magnetism due to that current causes eddy current losses and hysteresis losses to be manifested as heat in the projectile. The eddy current distribution in the projectile might be approximated by the formulae given by Steinmetz in Chapter 7 of his book "Transient Phenomena." The energy which manifests itself as heat penetrates the outer surface of the projectile at the cylindrical portion approximately inversely proportional to the

square root of the frequency. By controlling the strength and frequency of the current in the coil the heat supplied and the depth to which the heat penetrates the projectile 10 may be controlled and thus the projectile is differentially heated. The current is of such a value that the projectile is heated as rapidly as possible to the quenching temperature.

It is a known fact that when a body having a relatively small projection is heated there is a strong tendency for that projection to assume a higher temperature than the surrounding material. This phenomenon is observed especially in the case of cutting tools and for that reason a cutting tool is not made with a cutting edge that is too pointed. Accordingly, when the projectile 10 is heated there is a tendency for its tip or ogival head to assume a higher temperature than the surrounding material; this is desirable in the case of a projectile for the projectile tip or ogival head ultimately should be harder than the body of the projectile and the projectile material should be progressively less hard as the distance from the pointed end of the ogival head increases. In order that the tip or ogival head might not be overheated by the combined effect of the heat due to the eddy current and hysteresis losses in the tip or ogival head and the heat which is supplied from the surrounding material in accordance with the above phenomenon provisions are made so that the eddy current and hysteresis losses in the elemental parts of the tip or ogival head are not as large as that in corresponding elemental parts of the body portion of the projectile as measured from the projectile surface; this is accomplished by spacing the adjacent coil windings a greater distance from the shell tip than the distance between the body of the shell and its adjacent coil windings, i. e., the coil has an arcuately flared section 12 as indicated on the drawing and the tip of the projectile extends outside the arcuately end of the flared section a small amount whereby a greater amount of heat is generated in elemental parts of the body portion than in corresponding elemental parts of the ogival head as measured from the projectile surface.

The coil or modified solenoid 11 is formed from a hollow water cooled conductor similar to the one described in the Northrup Patent No. 1,328,336, issued on January 20, 1920 but it is understood that the cross section of the conductor may be solid, of "Litzdraht" or may take a variety of forms and shapes.

The coil or modified solenoid 11 is supplied from the high frequency source 13 through the double pole double throw switch 14. The contacts 15, 16 on switch 14 are not energized.

The quenching fluid is supplied from a source 17 through gate valve 18 and conduit 19. Gate valve 18 is normally closed and is opened when plunger 20 is moved due to the presence of a magnetic field in the coil 21. Such valves are well known in the art. The coil 21 may be connected to a direct current source of supply 22 through the double pole double throw switch 23. The contacts 24, 25 of switch 23 are not energized.

The control handles of switches 14 and 23 are rigidly connected together by the member 26 so that coils 11 and 21 cannot be energized simultaneously, i. e., the projectile cannot be heated and quenched at the same time. The particular arrangement of the member 26 on the switches serves another important function in that by a continuous movement of member 26 the quenching fluid may be caused to flow almost immediately after the projectile is heated to the hardening temperature; thus, the time during which grain growth in the projectile metal takes place is very short.

In the production of armor piercing projectiles, proper gradation of hardness from the point and outer skin surface to a tough core is essential; such proper gradation of hardness consists not merely in providing the projectile with a thin layer of hardened material but in providing the projectile with portions having different degrees of hardness along the projectile surface as well as in depth. The above mentioned Hadfield et al. Patent 1,381,633 on page 2, lines 18 to 30 relates to the degrees of hardness essential to the production of armor piercing projectiles having the proper gradation of hardness from the point and outer skin surface to a tough core.

My invention has been disclosed as applied to the heat treatment of an armor piercing projectile but my invention is not limited to the specific embodiment which is disclosed but might be applied in the heat treatment of objects other than armor piercing projectiles; it is understood that changes in the precise embodiment of the invention herein disclosed may be made within the scope of what is claimed without departing from the spirit of the invention.

I claim:

1. An induction heating apparatus for an armor piercing projectile having a body portion and an ogival head, an electrical air core modified solenoid having a cylindrical section adapted to have inserted therein said body portion and to encircle said body portion, and said modified solenoid having a flared section which is adapted to at least partially encircle said ogival head, said flared section being arcuately flared to such a degree whereby less unit heat is produced in the ogival head than in the body portion as measured from the projectile surface.

2. In the process of producing a zone hardened steel projectile gradated in hardness throughout its interior and in accordance with a predetermined pattern, said projectile having a body portion and an ogival head, the steps which consist in quickly differentially heating elemental parts of the projectile with correspondingly more heat supplied to the elemental parts of the body portion than the corresponding elemental parts of the ogival head as measured from the projectile surface, and then quickly quenching the projectile, whereby a projectile gradated in optimum degrees of hardness throughout the interior portions of the ogival head and body portion is produced with but one heating and quenching operation and with elemental parts of the ogival head correspondingly harder than elemental parts of the body portion as measured from the projectile surface.

3. In the process of producing a zone hardened steel shell having an ogival head and a body portion, the steps which consist in quickly supplying more heat per elemental part to the body portion than to corresponding parts of the ogival head as measured from the shell surface, said heat being supplied by differentially heating elemental parts of the body portion and differentially heating elemental parts of the ogival head, and then quickly quenching the body portion and ogival head whereby a shell gradated in optimum degrees of hardness throughout its interior is produced with but one heating and quenching operation and with elemental parts of the ogival head correspond-

ingly harder than elemental parts of the body portion as measured from the shell surface.

4. In the method of producing zone hardened steel ordnance projectiles having a body portion and an ogival head, the steps which consist in placing a modified solenoid having a flared section coaxially with the projectile axis in surrounding relationship to the body portion and with the flared section adjacent the ogival head, then energizing the solenoid with high frequency current, said flared section being arcuately flared to such a degree whereby less unit heat is generated in the elemental parts of the ogival head than in corresponding elemental parts of the body portion as measured from the projectile surface, and then quickly quenching the projectile whereby a projectile is produced gradated in a plurality of steps non-uniformly throughout the projectile body and with elemental parts of the ogival head harder than corresponding elemental parts of the body portion as measured from the projectile surface.

WALTER H. SODERHOLM.