

UNITED STATES PATENT OFFICE

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NONMAGNETIC ARMOR

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My invention relates to steel alloys suitable for use as armor plate and, particularly, to non-magnetic, hard, ductile products and the method of relating the alloy composition to its heat treatment to impart to the alloy the desired properties of hardness, ductility and magnetic permeability.

An object of my invention is to produce a steel alloy capable of developing ballistic properties at least as good as any of the alloys used as armor and in addition thereto to have the quality of being non-magnetic.

Another object of my invention is to provide a method of controlling the composition of the alloy to render it capable of developing the desired properties and, further, to provide a sequence of treating steps which will impart to it the hardness and ductility required of good armor plate yet will permit it to retain its non-magnetic quality.

In the past it has generally been accepted that a steel possessing a limit velocity of 1450 feet per second when 0.25 inch armor plate is tested with thirty caliber bullets represents a satisfactory combination of physical properties to make the material acceptable for use as armor plate. It has been found that such steels, because of their magnetic qualities, when used as armor plate in aircraft necessitate the removal of the compass to a wingtip in order to minimize effects on its behavior. The complications involved in the installation of remote compass reading equipment weigh heavily against the use of armor plate in aircraft.

My invention comprises the several steps and the relation of one or more of such steps with respect to each of the others which will be exemplified in the treating process hereinafter disclosed necessary to be carried out to produce said alloy, and the scope of my invention will be indicated in the claim.

It is well known in the metallurgical art that austenite is usually non-magnetic. Non-magnetic steels having austenitic structures are relatively common and are exemplified generally by the stainless steels. The austenitic structure of known steels and, hence, the stainless quality and, incidentally, the non-magnetic quality, is directly traceable to the identity of the particular alloying elements and their proportions. The austenitic structure in the stainless steels is ob-

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tained by adding large amounts of chromium, nickel or other alloying elements such as manganese which elements have the effect of inhibiting the austenite-pearlite transformation.

5 Austenitic steels although they are usually non-magnetic, and probably stainless, are generally soft. They can be hardened, but only at the cost of a considerable loss in ductility. Thus, armor plate generally represents a compromise between composition and attainable physical properties. Since extreme hardness and great ductility are the prime essentials of good armor plate, all else is sacrificed in the attainment of ultimate values of these two properties, very often by way of elaborately expensive alloying elements.

15 I have found that common alloy steels can be converted into extremely hard, highly ductile, non-magnetic and non-magnetizable products possessing ballistic properties at least as good as acceptable armor plate is the manganese content of the steel is balanced against the carbon content so that after cold working to the desired hardness the steel can be maintained at a temperature high enough to relieve the cold work stresses and im-

25 part ductility to the steel and yet not cause the precipitation of carbides from solid solution. The method of carrying out my invention and producing the alloy having the desired properties will be readily understood from the following examples:

30 Six samples of an iron alloy containing 0.90% carbon, 11% manganese, 0.60% silicon and 2.5% nickel were prepared and cold rolled to Brinnell hardnesses, respectively, of 294(1), 341(2), 415(3), 363(4), 363(5), and 363(6).

35 All of the samples were then given heat treatments to relieve internal stresses as summarized in the following table. The samples 1, 2, 3, 4, and 5, after heat treatment were non-magnetic and non-magnetizable.

40 Ballistic tests were performed on these samples and the results determined in terms of limit velocity of the specimen. Limit velocity is defined as the velocity of the bullet necessary to penetrate a plate such that the base of the bullet just passes through the plate. The nature of the fracture of the plate around the nose of the bullet when described in terms of the condition of the petals gives an indication of the ductility and

50 suitability of the material as armor plate.

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The following table summarizes the results of the ballistic tests:

Sample	Hardness After Cold Roll	Stress Relieving Temperature	Results of Ballistic Tests
1.....	294	550° C.....	Ductile, low limit velocity.
2.....	341	550° C.....	Ductile satisfactory, limit velocity.
3.....	415	550° C.....	Too hard sample, brittle.
4.....	363	Not stress-relieved..	Low limit velocity, all petals off.
5.....	363	450° C.....	Limit velocity 1500' sec., all petals on.
6 ¹	363	600° C.....	Plate cracked, very brittle.

¹ Metallographic examination revealed heavy carbide precipitation.

From the data summarized in the above examples and in the table, it is apparent that a non-magnetic armor having excellent ballistic properties can be produced by so balancing the manganese and carbon contents of the steel that the carbide precipitation temperature of the alloy will lie above its stress relieving temperature.

Since many changes may be made in the composition of the armor plate and thus many embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description shall be interpreted as illustrative and not in a limiting sense.

The invention described herein may be manufactured and used by or for the Government of

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the United States of America for government purposes without the payment of any royalty thereon or therefor.

Having described my invention what I claim as new and desire to secure by Letters Patent of the United States is:

A hard, ductile, non-magnetic steel armor plate consisting substantially of 11 percent manganese, 2.5 percent nickel, 0.60 percent silicon, and 0.90 percent carbon, the balance being iron and small quantities of residual elements commonly occurring as impurities in steel, made by the method, comprising cold-rolling the austenitic plate to a hardness of 363 Brinnell and heating the cold-rolled plate at a temperature of 450° C. to relieve internal stresses.

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