Aug. 27, 1957 B. C. ESSIG ET AL 2,804,413

CARBURIZATION OF METAL ARTICLES

Filed Dec. 22, 1955

Fig. 1

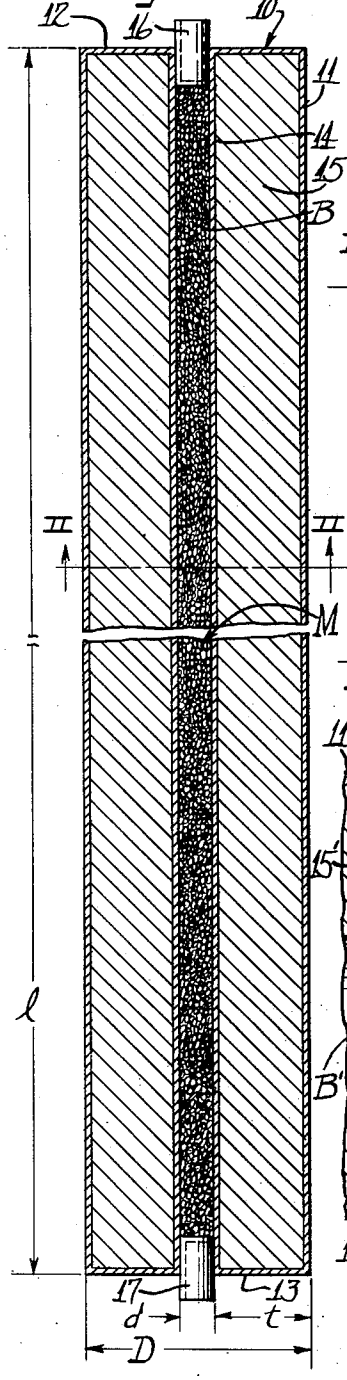


Fig. 2

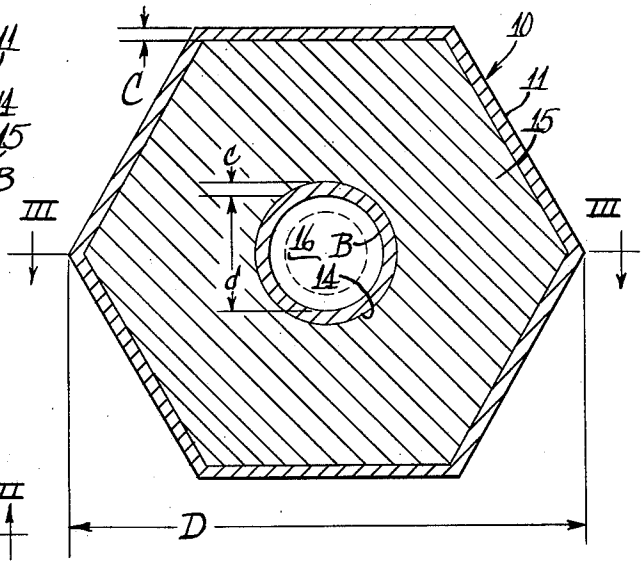


Fig. 4

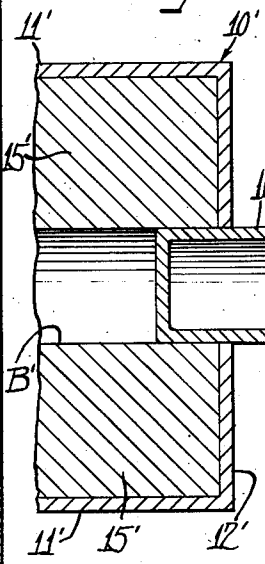
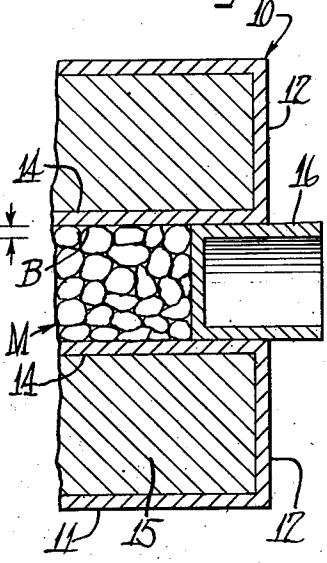


Fig. 3



Inventors
Benjamin C. Essig
Floyd R. Anderson
by Kirschstein, Ottinger, Israel & Schiffmiller Attys

United States Patent Office 2,804,413
Patented Aug. 27, 1957

2,804,413

CARBURIZATION OF METAL ARTICLES

Benjamin C. Essig and Floyd R. Anderson, Denver, Colo., assignors to Gardner-Denver Company, Denver, Colo., a corporation of Delaware

Application December 22, 1955, Serial No. 554,768

4 Claims. (Cl. 148—19)

This invention relates to a process for case hardening hollow metal members, and more particularly, to an improved process for case hardening the exterior of such members which may have difficultly accessible interior surfaces, while controlling the extent of case hardening of the interior surfaces.

Although the instant invention may have application in a number of fields, particularly those involving the case hardening of exterior surfaces only (as in bearings) and also those involving the case hardening of both the interior and exterior surfaces of elongated hollow articles having relatively thin body portions separating the interior and exterior surfaces, the instant invention is particularly adapted to the formation of a novel drill rod structure. The so-called "rock drill rods" have generally accepted standard sizes ranging from about 2 to about 20 feet in length and from about 0.75 to 2 inches in diameter. Actually, hexagonally cross-sectioned rods are usually employed with maximum cross-section dimensions of ⅞ inch up to 1⅞ inch (but such dimensions are considered to be "diameters" of a substantially round cross-section for the purposes of the instant description). The rods are formed from steel stock by hot or cold working usually over a suitable mandrel, which results in the formation of an approximately ¼ inch axial bore in the rods. Although the particular manner in which the bore is formed in the rods is not so important, this bore does extend the entire length of the rod and the ratio of bore length to bore diameter is very substantial.

Heretofore, drill rods have been made of high carbon steels which are difficult to work; but it has only recently been discovered that drill rods giving distinctly superior performances may be made from steels having a lower carbon content which are case hardened on both the outside surface and the inside surface defining the axial bore. The case on the interior surface is very important here, and it should be about equal in thickness to the exterior case. A number of difficulties, however, have been encountered in attempting to fabricate such a case hardened drill rod.

In general, the case hardening process involves first a cementing or carburizing step and then a quenching step wherein the hot carburized article is immersed in a quenching liquid such as water or oil so as to quickly cool the article from substantially the carburizing temperature to substantially room temperature (or at least to a temperature of about 300° F. so that further metallurgical changes do not occur on cooling to room temperature). The carbon content of the carburized surface portions as well as the rate at which such surface portions are quenched will determine the hardness and other desirable properties in the case hardened layer. Differences in case thicknesses particularly in the difficultly accessible interior surfaces may cause defects. Also, different quenching or cooling rates for different surface portions may make such a significant difference in the resulting material that

flaws or defects may be created, if such surface portions are adjacent. In addition, excessive warpage, over and above that which may be obtained using ideal carburizing and quenching techniques, may result from lack of uniform quenching.

A peculiarity of drill rods and similar hollow articles having difficultly accessible interior surfaces is uniform carburization of the interior surfaces is difficult and that uniform quenching of such surfaces by contact with the quenching liquid cannot be obtained.

For example, the carburization operation per se presents a number of problems. Uniform carburization with gas has been found to be practically impossible because of the difficulty in having a uniform concentration of gas throughout the bore. Packing the rods in solid carburizing material also presents difficulties not only in the tendency for slightly slower carburization (which is actually a gas-solid reaction) within the bore but also in the tendency to bend the rods so packed because of shifting of the carburizing material during carburization. Liquid carburizing baths (KCN) present safety hazards.

As another problem, the initial quenching liquid entering the bore is only a very small amount of liquid which engages a rather substantial amount of heated surface and this results immediately in vaporization of the quenching liquid which, in the case of such drill rods, has been found to violently force vapor and liquid out of the opposite end of the bore. Such a fast flowing stream of heated steam or oil which is very hazardous and difficult to handle is undesirable. In addition, the surfaces of the bore are not uniformly contacted with liquid, because of the presence of vapor in the bore, so that certain of the difficulties hereinbefore mentioned are encountered.

Certain procedures have been suggested for overcoming the problems peculiar to this art. One procedure contemplates filling the bore of the rod with a normally solid carburizing material and sealing such material in the bore so that contact with the bore thereby at carburizing temperatures will result in a uniform carburization at a predetermined rate. The rod itself is heated to carburizing temperatures in a carburizing fluid which will, of course, be exposed only to the exterior surfaces of the rod and which also carries out carburization of such exterior surfaces uniformly and at a predetermined rate. Preferably, the rod is suspended from one end in the carburizing fluid to minimize bending or warpage. In addition, the concentration of the carburizing material in the fluid can be controlled so that the carburizing rate is controlled and the resulting case thicknesses on the inside and outside surfaces may have the desired ratio. For example, diffusion techniques may be employed to correlate the two carburizing rates in a situation wherein the solid carburizing material in the bore is somewhat slower. In such situation, carburization in a gas atmosphere can be carried out to the extent desired on the exterior surface of the rod and the rod can then be maintained at carburization temperatures in a substantially inert atmosphere (or an atmosphere which will not cause decarburization) for an additional period of time, during which "diffusion" takes place along the exterior surface and additional carburization may take place in the bore of the rod.

Although quenching by actual surface contact between the quenching liquid and the surface to be case hardened had been considered a necessary aspect of the procedure, another suggested solution provides a process which avoids this procedural step with respect to the difficultly accessible interior surfaces of the article, while still obtaining case hardening thereof. In other words, this procedure contemplates quenching the rod by contacting the outside surface only thereof with the quenching liquid,

while preventing contact between the quenching liquid and the inside surface. This is accomplished by sealing the open ends of the bore before carburization and retaining the seal during quenching; and this procedure is based in part on the discovery that the somewhat less rapid cooling of the interior surfaces by heat conduction through the thin shell or body of the rod results in not only an extremely uniform but also an effective case hardening of the interior surface. The uniformity of the interior surface case hardening has been found to be particularly important from a strength and performance point of view.

Certain difficulties have been encountered in carrying out the foregoing suggested procedures primarily in the discovery of a suitable plug for this purpose. An ordinary solid steel plug can be used, but certain difficulties are encountered. For example, it is important to effectively seal the opening or bore with a plug. Threads or comparable sealing means require additional machining in the rod as well as the plug and are not economically practical, because carburizing of the plugs during repeated use thereof quickly renders them useless. Force-fitting of the solid steel plug appears to afford the most practical seal, although it will be appreciated that such force-fitting involves the use of relatively great forces which tend to cause distortion of the plugs and/or the rods. After the quenching step has been completed it is found that the plugs are substantially "frozen" in the bores or holes and a considerable amount of difficulty is encountered in removing the plugs. In Snyder U. S. Patent No. 2,398,809 there is disclosed a ceramic plug which is employed (with ceramic sealing means) to seal the opposite ends of a bore for an article which is to be carburized on the outside or exterior surface only. The Snyder plug has the advantage that it fractures upon quenching, so that the problem of removing the plug is allegedly avoided. The difficulty here, however, is that still greater difficulties are encountered if the liquid penetrates the bore and contacts the solid carburizing material retained therein in the drill rod. In fact, the Snyder plug is wholly ineffective for use in the instant drill rod carburization because it permits contact between the quenching liquid and the carburizing material in the bore of the rod. Comparably unsatisfactory results are obtained using the Snyder plug and particular decarburizing material which may be retained in a bore or hole in an article to prevent carburization therein, for example, as described in Davis U. S. Patent No. 2,275,133.

The instant invention is based upon the discovery of a new type of plug which can be used to advantage in the suggested drill rod carburizing procedures hereinbefore outlined as well as in various other carburizing procedures involving the case hardening of surface portions of a ferrous metal article having at least one opening therein (whether or not case hardening of the interior surfaces of the opening is desired). The instant plug is formed of thin low carbon steel sheet which is soft enough to be conveniently force-fit into an opening so as to seal the same; and which is sufficiently thin to be carburized throughout substantially its entire body during the carburization operation. This plug will stand up under the quenching operation so as to prevent contact between the quenching liquid and the interior of the opening which it seals; but this plug becomes so embrittled by the carburizing and subsequent quenching operation that it may be readily fractured when its removal is finally desired.

It is, therefore, an important object of the instant invention to provide an improved case hardening operation for ferrous metal articles having at least one opening therein.

It is a further object of the instant invention to provide an improved method of case hardening surface portions of a ferrous metal article having at least one opening therein, which comprises force-fitting a plug formed of thin low carbon steel sheet into the opening to seal the same, carburizing the surface portions and simultaneously the entire body of the plug, quenching the article and breaking the plug to remove the same from the opening.

Other and further objects, features and advantages of the present invention will become apparent to those skilled in the art from the following detailed disclosure thereof and the drawings attached hereto and made a part hereof.

On the drawings:

Figure 1 is a sectional elevational view of a case hardened drill rod made by the process embodying the instant invention, and shown with sealing means closing the open ends of the bore;

Figure 2 is an enlarged cross-sectional view of the drill rod of Figure 1 taken substantially along the line II—II of Figure 1;

Figure 3 is a cross-sectional view taken substantially along the line III—III of Figure 2; and

Figure 4 is a view comparable to Figure 3 showing a different arrangement for use in the instant invention.

As shown on the drawings:

In Figure 1, the reference numeral **10** indicates generally a drill rod embodying the instant invention at the completion of the quenching step. The drill rod **10** has a case hardened layer **11** defining its outer peripheral surface, case hardened layers **12** and **13** defining, respectively, the top and bottom end surfaces of the rod **10** and a case hardened surface portion or layer **14** defining an axial bore B extending the full length of the rod **10**. Actually, the rod **10** comprises a first case hardened sleeve **14** defining the axial bore B, a second case hardened sleeve **11** defining the outer surface for the rod **10** and a steel body **15** interposed between the first and second case hardened sleeves **11** and **14**. This structure has been found to be uniquely satisfactory for drill rods.

As shown in Figure 1, the overall length *"l"* of standard drill rods may range from 2 to 20 feet, whereas the maximum cross-sectional dimension or diameter "D" may be from ¾ to 2 inches and the diameter *"d"* of the bore B is customarily about ¼ inch. Although it is standard commercial practice to employ a bore diameter *d* of approximately ¼ inch, it will be appreciated that this dimension *d* may range from as little as about ⅛ inch to as much as about ½ inch for the purposes of the instant invention. Because of the manner in which the bore B is usually formed during working of the steel, it is ordinarily not perfectly circular but only approximately so and the dimension *d* represents generally the average diameter (or corresponding average cross-sectional dimension).

As will be noted from Figure 2, the overall cross-section of the rod **10** is hexagonal and the maximum cross-sectional dimension D is the dimension hereinbefore indicated and, for the purposes of the instant invention, the dimension D may be considered to be a diameter of a substantially round cross-section (or substantially the average cross-sectional dimension).

As will be seen, the ratio of the bore length *l* to the bore diameter (on the basis of the standard bore diameter of ¼ inch) ranges from a minimum of about 100:1 to a maximum of about 1000:1 (although the maximum is actually unlimited for practical purposes). The minimum ratio of 100:1 for *l*:*d* has been found to be generally definitive of a difficultly accessible interior surface for the purposes of the instant invention, in that problems in quenching are definitely apparent at this minimum ratio and for any larger ratio. Another feature here involved is that the wall thickness *t* (Figure 1) for the rod portion surrounding the bore B may range from about ¼ inch to a maximum of about 1 inch in order to obtain the best chilling or quenching effect on the case hardened layer **14** by the instant quenching process. Wall thicknesses substantially greater than this dimension will serve

to slow down the cooling through the body of the rod to too substantial an extent to obtain the best results.

The first step in the practice of the instant invention is the carburizing step wherein both the inside surface layer **14** of the rod and the outside surface layer **11** of the rod are carburized. Carburization per se (sometimes referred to as "cementation") is a well known process, which comprises exposing the surface to be carburized to a carburizing material at carburizing temperatures. The carburizing material may be solid or fluid. For example, charcoal and/or coke in combination with chemical energizers in particulate compositions such as are described in Rodman U. S. Patents Nos. 949,448 and 1,432,416 may be employed. Also, a bath of a salt containing carbon, such as a potassium cyanide salt bath may be employed as a liquid carburizing material; or a hydrocarbon such as natural gas may be employed as a gas carburizing material. In such carburizing processes which may be used in the practice of the instant invention the carbon begins to penetrate the steel surfaces at about 1300° F., but temperatures up to as much as 2000° F. may be used to accelerate the process. Preferably, a carburizing temperature of 1650 to 1700° F. is employed.

In the practice of the instant invention, the first process step is that of filling the bore B with particulate carburizing material M. Such particulate carburizing material may be in the form of potassium cyanide salt particles (with or without other carburizing particulate materials such as those mentioned by Rodman) but if such particles of a salt containing carbon are to be used as an essential ingredient in the particulate carburizing material which fills the bore B, it is necessary to pack such particles in the bore rather tightly in order to assure contact between the carburizing material and the bore walls **14** at the carburizing temperatures. In other words, the salts of this type melt at the carburizing temperatures and, if packed loosely in the bore B, might only fill the lower portion of the bore B when melted. Preferably, the particular carburizing material used is a refractory material or a material which remains solid at carburizing temperatures. By the use of such refractory materials it is possible to maintain close contact between the carburizing material and the bore walls **14** in a uniform manner throughout the bore B. Preferably, the particulate carburizing material is a coked carbonaceous material such as coked charcoal, coal, etc., which contains a small amount of energizer (i. e. 1 to 20% by weight) such as an alkaline earth carbonate or an alkali metal carbonate, which has been ground down to a fine particle size (e. g. suitable to pass an 8 mesh screen) so that it can be conveniently fed into the bore B.

Referring to Figure 1, it is generally preferable to maintain the rod **10** in an upright position, and a bottom steel plug **17** is force-fit into the bottom of the bore B, and the particulate material is then poured into the bore B so as to completely fill the same. Then, the top steel plug **16** is force-fit into the top of the bore B. At this point in the process, it will be apreciated that the carburized layers **11**, **12**, **13** and **14** are not yet on the rod **10**.

In the next step, the rod **10** is suspended by its upper end in the furnace so as to hang freely. This is of particular advantage since it tends to eliminate a substantial amount of warpage in the rod **10** during carburization; and this is one of the reasons for employing a fluid carburizing material to carburize the outer layer **11** of the rod **10**. In the furnace the rod **10** may be suspended by its upper end in a fluid carburizing material such as a bath of a molten salt containing carbon (such as a potassium cyanide bath). One disadvantage of the use of potassium cyanide is the safety factor in view of the poisonous character of the fumes; but better control of carburization can also be obtained using a gas carburizing material as the fluid carburizing material herein. An important feature resides in the fact that the inner case thickness or depth *c* and the outer case thickness or depth C may be controlled adequately during the instant operation, so the use of gas for a more easily controlled carburization of the outer layer **11** is of particular advantage. Gases which may be used as carburizing fluids contain, as the carbon bearing component, such materials as natural gas, volatilized higher hydrocarbons, etc.

The time at which the ferrous metal surface is exposed to the carburizing material at the carburizing temperature will, of course, determine the depth of the carburized layer and the depth of the resultant case hardened layer. For the purposes of the instant invention the carburized or case depth *c* and C on the inside and outside surfaces, respectively (Figure 2) may range from about 0.010 to about 0.125 inch for the practice of the instant invention, although the preferred case depth *c* and/or C for use in the practice of the instant invention in the fabrication of drill rods is 0.050 to 0.090 inch (preferably *c* and C are 0.05–0.07 D). The carbon content in these carburized portions is 0.8–1.2%.

As a typical example, using a 1½ inch hexagonal cross sectioned SAE 4320 steel, 20 foot drill rod having a ¼ inch axial bore, the bore is completely filled with a solid carburizing material, in particulate form suitable to pass an 8 mesh screen, composed of coked charcoal and/or coal (100 parts by weight), barium carbonate (5 parts by weight) and sodium carbonate (5 parts by weight) and sealed with plugs **16** and **17** which will be described. The rod is then suspended freely from one end thereof in a furnace, heated (in an inert atmosphere) to 1700° F. then natural gas is fed into the furnace (at 200 cu. ft./hr.) to create a carburizing atmosphere; and the rod is maintained at 1700° F. for 8 hours which is followed by a 2 hour diffusion period at 1700° F. in an inert atmosphere. This results in carburized layers **11** and **14** on the outside and inside surfaces having carburized depths C and *c* each of 0.080–0.090.

Comparable results are obtained by maintaining the same rod immersed in a molten potassium cyanide bath for the same period of time and at the same temperature.

If either of the foregoing procedures is repeated except that a ⅞ inch hexagonal cross-sectioned SAE 8620 steel, 10 foot drill rod having a ¼ inch axial bore is employed at a carburizing time of 4½ hours and a diffusion time of 1½ hours, the resulting carburized outside and inside depth C and *c* are each 0.05–0.06 inch.

The sealing of the opposite ends of the axial bore B, in each case, is accomplished merely by force-fitting the dish-shaped or thimble-shaped plugs **16** and **17**, respectively, therein. In the instant examples, the thimbles **16** and **17** are formed of 0.015 inch thickness SAE 1010 sheeting.

Quenching in the customary manner from the carburizing temperature (or from a temperature of at least about 1500° F.) is carried out by plunging the carburized rods into quenching oil (or optionally water). During the quenching, the rods are quickly cooled to a temperature which may be considered to room temperature, in that the temperature is low enough (perhaps 300° F. or less) that further metallurgical changes do not take place on cooling to room temperature.

After quenching of the carburized rods, it is found that the plugs **16** and **17** still form an effective seal for the axial bore so as to substantially prevent penetration of the quenching liquid into the bore. The plugs are also very brittle and may be easily broken. After the plugs are broken it is found that the particulate carburizing material within the bore may be removed quite easily therefrom. If the bore had not been effectively sealed during the quenching operation, the carburizing material can be removed only with a great deal of difficulty.

The dished-shape of the instant plugs **16** and **17** is important since this shape permits the adequate sealing of the bore with a material which has, in and of itself,

a minimum thickness so that carburization thereof throughout substantially the entire body can be accomplished with ease. Preferably, the thickness of the steel sheet employed in the thimbles **16** and **17** is less than the desired thickness (C or *c*) of the ultimate case hardened layer or layers. The best results are obtained if the sheet thickness is from about 5 to 50% of the depth C or *c* of case hardening. Thimble shaped (cold drawn) 20 gauge (0.035 inch thickness) or thinner rolled sheet stock are preferred, although sheet thicknesses ranging from about 0.1 inch to a minimum of about 0.010 inch (below which the material is too weak) may be employed.

In general, the sheet steel employed in the plugs **16** and **17** is a low carbon steel which may be easily force-fit into the desired opening and which will become sufficiently embrittled with the increased carbon content resulting from carburization. Such sheet may have about 0.05–0.30% C, and preferably has only about 0.30–0.90% Mn. This involves the steels within the range of SAE 1006 to SAE 1030 (except for SAE 1019, 1022, 1024 and 1027 which have a sufficiently higher Mn content to give inferior cold working properties). Actually the force-fitting of the plugs **16** and **17** into the bore is in the nature of a cold working operation and steel too brittle for this purpose should not be used. Since the plugs are used only once, it is pointless to use more expensive steels than those of the SAE 1000 series (even though such steels are operative); but the principal consideration is the carbon content which will permit embrittlement during carburization and quenching.

Although the instant invention has been described herein primarily in connection with the formation of drill rods, it will be appreciated that the instant invention may have application in any of a number of carburizing procedures involving the case hardening of both the interior and exterior surfaces, particularly of elongated hollow articles such as the drill rod. On the other hand, the instant invention may also be used to advantage in a procedure such as is outlined in the aforementioned Snyder U. S. Patent No. 2,398,809, for example, in a procedure wherein the outside of a bearing is to be case hardened without case hardening the interior surface thereof. The arrangement employed for this purpose is shown partially in Figure 4, wherein it will be seen that a bearing **10'** having an axial bore B' may have a plug **16'** of the thimble shape here employed force-fit into the bore B' so as to prevent carburizing vapor from entering the bore B' during the carburizing process. In such a procedure the carburizing conditions described in the previous examples relating to drill rods may be used exactly as described so as to obtain a carburized layer **11'** around the outer periphery of the bearing body **15'** and a carburized layer **12'** at the end. When the resulting bearing **10'** is quenched the thimble **16'** is rendered brittle and can be easily broken and removed from the bore B'. It will also be appreciated that the bore B' could be filled with particulate decarburizing material (as described in the aforementioned Davis U. S. Patent No. 2,275,133); and the thimble **16'** is thus used to additional advantage in that it prevents contact between the particulate material and the quenching oil or water. Such particulate decarburizing material might be found to be useful in instances involving very extensive and deep carburization of the bearing surface **11'**, since such a procedure might result in a small amount of leakage of carburizing vapors through or past the plug **16'**. Actually, the plug **16'** is made of sufficiently formable material to permit the formation of a very accurate and lasting seal. The thimble shape of the plugs **16**, **16'** and **17** herein shown has been found to be uniquely superior for the purposes here involved, and the plugs are preferably preformed to the thimble shape. Actually, it will be appreciated that the formation of a plug of comparable shape could be obtained merely by placing a steel sheet across the mouth of the bore B and then forcing the sheet into the bore to the extent desired with a suitable tool.

It will be understood that modifications and variations may be effected without departing from the spirit and scope of the novel concepts of the present invention.

We claim as our invention:

1. A method of case hardening surface portions of a ferrous metal article having at least one opening therein, which comprises force-fitting a plug formed of thin low carbon steel sheet which becomes brittle upon carburization and quenching into the opening to seal the same, carburizing the surface portions and simultaneously the entire body of the plug, quenching the article and thereafter breaking the plug to remove the same from the opening.

2. A method of carburizing a steel drill rod having an axial bore that comprises filling the bore with particulate carburizing material, force-fitting a plug formed of thin low carbon steel sheet which becomes brittle upon carburization and quenching into opposite ends of the bore to seal the same, heating the rod to carburizing temperature in the presence of a carburizing fluid, whereby carburization of the surface defining the bore, the entire body of the plugs and the outside surface of the rod is accomplished, quenching the rod with the plugs retained therein, and thereafter breaking the plugs to remove the same from the opening.

3. A method of carburizing a steel drill rod having an axial bore that comprises filling the bore with particulate carburizing material that remains solid at carburizing temperature, force-fitting a plug fomed of thin low carbon steel sheet which becomes brittle upon carburization and quenching into opposite ends of the bore to seal the same, suspending the rod from one of its ends, heating the rod to carburizing temperature in the presence of a carburizing fluid, whereby carburization of the surface defining the bore, the entire body of the plugs and the outside surface of the rod is accomplished, quenching the rod with the plugs retained therein, and thereafter breaking the plugs to remove the same from the opening.

4. A method of carburizing a ferrous metal article having an elongated hole therein, which comprises filling the hole with particulate carburizing material that remains solid at carburizing temperature, sealing the material therein with low carbon steel sheet which becomes brittle upon carburization and quenching, heating the article to carburizing temperature in the presence of a carburizing fluid, whereby carburization of the suface defining the hole, the steel sheet and the outside surface of the article is accomplished, quenching the article, and thereafter breaking the steel sheet and removing the particulate carburizing material from the hole.

References Cited in the file of this patent

UNITED STATES PATENTS

1,459,409	McQuaid	July 19, 1923
2,398,809	Snyder	Apr. 23, 1946