April 28, 1953 A. BRENNER 2,636,849

METHOD OF ELECTROFORMING GUN BARRELS AND LINERS

Filed Dec. 13, 1946

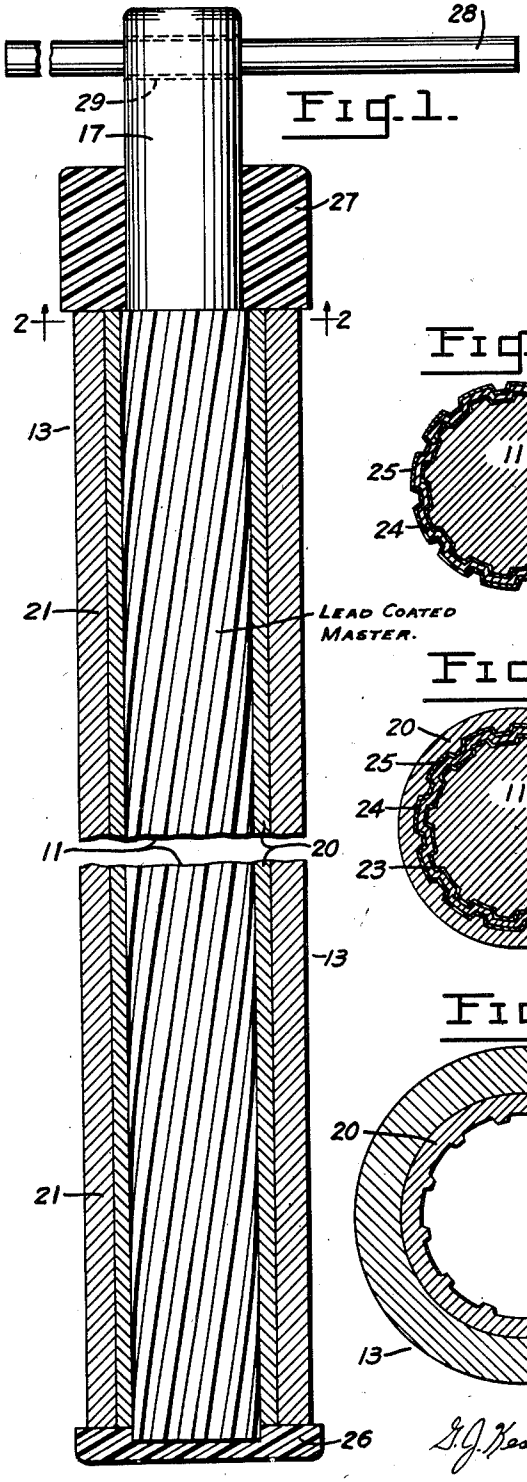


Fig. 1.

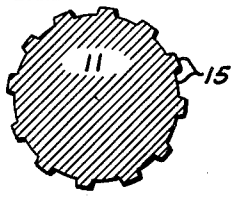


Fig. 2.

Fig. 3.

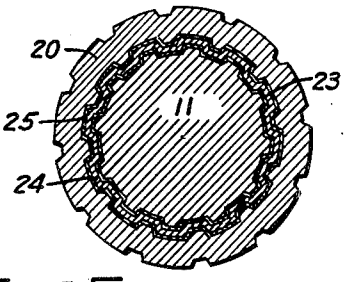


Fig. 4.

Fig. 5.

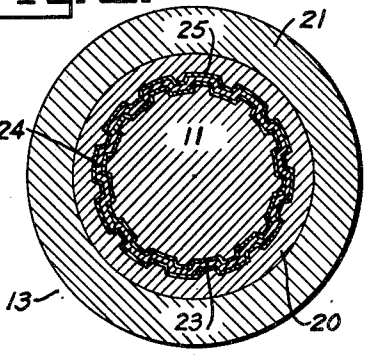


Fig. 6.

Fig. 7.

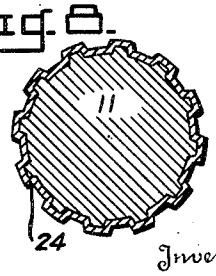


Fig. 8.

Inventor
ABNER BRENNER.

By G. J. Kossenich, J. W. Church & F. E. Thibodeau
Attorneys

Patented Apr. 28, 1953 2,636,849

UNITED STATES PATENT OFFICE

2,636,849

METHOD OF ELECTROFORMING GUN BARRELS AND LINERS

Abner Brenner, Chevy Chase, Md., assignor to the United States of America as represented by the Secretary of War

Application December 13, 1946, Serial No. 715,921

6 Claims. (Cl. 204—9)

(Granted under Title 35, U. S. Code (1952), sec. 266)

1

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

My invention relates to methods of making gun barrels, barrel liners and the like; and it has particular reference to techniques for manufacturing rifled gun barrels and liners from certain relatively hard metals.

Broadly stated, a principal object of my invention is to provide a method for making rifled-bore gun barrels and liners out of metals, such as cobalt, tungsten, molybdenum and alloys thereof, which are too hard to machine or cast by the usual commercial processes.

A more specific object of my invention is to provide a method for making rifled gun bores without having to form the riflings by conventional machining, swaging or broaching operations.

Another object is to simplify the manufacture of gun barrels and liners whose walls have variously designed tapers and whose bores have complex riflings.

A further object is to reduce the time and effort needed to make such gun barrels and liners.

A still further object is to improve the economy of gun manufacture.

The exact manner in which I accomplish these objects will become evident as this disclosure proceeds. Briefly stated, however, the process consists of electroforming gun barrels or liners by plating a suitable metal or alloy upon a "master." This "master" is a precision-made "negative" of the lands and grooves comprising the desired bore riflings of a gun barrel or liner.

The plating upon the "master" is carried on until a sheath-like "positive" is built up thereabout to a suitable thickness. This "positive," which is actually an electroformed gun barrel or barrel-liner consists of a tube whose bore faithfully reproduces the lands and grooves of the "negative" or "master." When completely formed, the newly formed barrel or liner is then removed from the "master" and machined on its outer surface to its required outside diameter. The "master" is used over and over again in repeating the process just outlined.

A preferred form of the "master" used in practicing my invention and the product which can obtained thereby may be seen by reference to the drawings wherein:

Fig. 1 illustrates in longitudinal section a typical "master" or steel "negative" of the required rifled gun bore, upon which a gun barrel comprised of two different metallic layers has been electroformed, together with various fittings used in the plating process;

2

Fig. 2 is a cross sectional view taken from line 2—2 of the Fig. 1 rifled "master" without showing the electroplated metal coatings included in the Fig. 1 illustration;

Fig. 3 shows the Fig. 2 "master" after it has been electroplated first with a thin layer of copper, then a thicker layer of lead, and finally a "flash" coating of copper;

Fig. 4 depicts the result of electroplating a layer of hardenable gun-metal upon the previously copper and lead plated "master" shown in Fig. 3;

Fig. 5 repeats the view of Fig. 4 except that the exterior of the hardenable gun-metal layer has been ground to provide a smooth surface which is necessary in cases where a gun barrel liner is being made. The thus ground, plated "master" is also a prerequisite in cases where a complete gun barrel is produced by this invention as will be evident from the next drawing;

Fig. 6 shows the Fig. 5 product upon whose hardenable metal layer has been electroplated a layer of softer and less expensive metal to form a complete, rifled gun barrel;

Fig. 7 shows the complete electroformed gun barrel of Fig. 6 from whose bore the "master" has been extracted; and

Fig. 8 shows a "master" similar to that of Fig. 2, etc., but made of metal other than steel, the external surface thereof being coated with an electroplated layer of lead.

The art of gun barrel and gun liner manufacture has undergone successive improvements designed to speed up and reduce the costs of their manufacture. Thus, for example, delicate machining of gun bore riflings (lands and grooves) has given way to swaging or broaching operations in making the barrels of many small arms weapons and barrel liners for larger caliber guns. At the same time, the concomitant metallurgical improvements which have been made for the purpose of increasing the resistance of the gun barrels or liners to erosion and corrosion, have likewise increased the hardness of the gun metals to the point where machining or broaching operations are no longer feasible. In fact, these metals are so hard that they are not capable of being put to practical use by employing conventional casting methods.

Thus, the problem has been to develop a method whereby gun barrels and liners can be economically and satisfactorily mass-produced from the very hard, corrosion and erosion resisting metals

now known to be most useful in gun manufacture. Examples of such metals are cobalt, tungsten, chromium, molybdenum and various alloyed combinations thereof.

As earlier mentioned, I have invented a method whereby rifled gun barrels and liners can be made from the aforementioned hard or hardenable metals without resorting to any difficult machining, broaching or casting operations. This method is fast, very economical and capable of producing barrels and liners with excellent gun bore riflings (such as are represented by **14** in Fig. 7), as the following description of my method will make clear.

To begin with, I make a master **11** or negative mold of the bore of the gun which is to be manufactured. This master **11** may take the form of a cylinder or rod whose outer wall is shaped exactly like the interior bore of the gun being made, thus forming an exact "negative counterpart" having "negative riflings" **15** (see Figs. 1–2) of the desired gun's bore riflings **14** (see Fig. 7).

In making master **11**, I preferably utilize a steel rod, machining the necessary "negative riflings" **15** (see Figs. 1–2) on the rod's outer wall. However, other methods and metals may be used. For example, the master can be made by casting a low melting alloy, such as babbit metal, into a mold. Still another technique is to cast or plate a soft metal such as lead or babbit metal around a steel rod, and then provide the necessary negative lands and grooves thereon by drawing the thus coated rod through an appropriate die. Regardless which method is used for making this master, and notwithstanding the complexity of the required gun bore's riflings and wall taper, the job of making one such master by "external" machining, etc., is obviously much simpler than the job of making numerous gun barrels or liners whose bores require individual "internal" machining or other operations.

Having thus obtained the master **11** (see Figs. 1 to 7), the actual process of electroforming rifled gun barrels or layers is now capable of being carried out. The first step is to attach an extractor **17** (see Fig. 1) to the master. This attachment may be made by threaded connection (not shown) or by any other convenient means. In fact, it is possible and may even be preferable to make the extractor a continuous unit of the master.

The next step is to carefully polish the master to remove burrs or other surface imperfections. This is important because those imperfections would cause nodules in the gun barrel or liner that is subsequently plated upon the master, or even prevent the master's easy removal from the resultant electroformed product.

The master is then prepared for the electroforming operations to follow by attaching at its free end (i. e., not the end to which the extractor **17** is attached) a plastic cap **26** (see Fig. 1). This cap **26** may be designed so that it can be press-fitted onto the master and act as a "mask" to prevent metallic electrodeposition beyond a certain desired area on the master. Obviously, however, any other means of attaching this plastic cap or in fact any other conventional type of masking device may be used for this purpose.

On the other end of the master, namely, that to which the extractor **17** is connected, another masking device such as the plastic cap **27** shown in Fig. 1 should be attached. One convenient way of installing cap **27** is to slidably remove the handle bar **28** from the opening **29** which extends transversely through extractor **17**, slip the plastic cap over the extractor into the illustrated snug fitting or press-fitted relationship therewith, after which the handle **28** may be returned to the position in the extractor which Fig. 1 shows.

The master to be electroplated having thus been properly protected so that the actual plating operations will produce the rifled barrel or liner of desired dimensions, and also so that the extractor **17** will not become plated with the metallic coatings, the actual electroforming steps can be begun.

When the master **11** is made of steel, a preferable procedure is then to apply thereon a copper coating **23** about 0.0005 inch thick (see Figs. 3–4–5–6), from a cyanide bath. Note: Use of such a copper coating, while optional, is desirable as an added precaution against corrosion. Whether or not this copper coating is applied, the next step is to electroplate an approximately 0.0003 inch coating of lead **24** (see Figs. 1–3–4–5–6) or other low melting point metal. If a non-corrosive metal such as stainless steel or non-ferrous metal is used for the master there is no need for a first coating **23** of copper and, instead, the lead coating **24** is applied directly thereon as shown in Fig. 8.

As will later become apparent, the product being electroformed by my process is removable without damage from the master because this lead envelope **24** (which coats the master **11** Figs. 3–4–5–6) can be melted at a temperature considerably lower than that which would have any effect on the master or the product electroformed therearound. The reason for using lead, in addition to its having a relatively low melting point, is that lead does not readily diffuse into the steel or copper of the master. If this should happen, it would prevent the electroformed product (barrel **13**) from being slipped off the master.

Other metals, for example cadmium, could be used in place of lead. Care must be taken, however, to employ a metal which will not alloy (as does tin) with the metals it comes into contact with, as this would cause a "bond" between master **11** and the electroformed product that would make their later separation difficult.

At this point, the lead coated master **11** is polished by any desired means to provide a smooth, bright surface. A preferred technique is electropolishing, and a suitable material for use in that process is a mixture of acetic anhydride and perchloric acid. After polishing the leaded surface, a "flash" or thin coating **25** of copper from a cyanide bath may be utilized to assure that the outside wall surface of the master **11** is perfectly clear and smooth preparatory to plating the desired gun barrel or liner thereon. At this stage, the master **11** appears as illustrated in Figs. 3–4–5–6.

The thus polished master **11**, optionally provided with a copper coating **25**, is then placed in an electrolytic bath containing in solution the salts of the metals from which the gun barrels or liners are to be electroformed. The choice of metals from which to make the gun barrels or liners may vary depending on the requirements of the user. Examples, as earlier mentioned, of the more desirable hardenable metals which may be used include cobalt, cobalt-tungsten alloy, cobalt-molybdenum alloy, etc. The temperature of the electrolytic bath should always be somewhat below the melting point of the lead (or other) coating which has been applied to master **11**, or else that coating would melt during this electroplating operation.

The entire gun barrel or liner may then be plated with the chosen metal about the master 11 until the necessary wall thickness of the finished product is attained. Or, if preferred, the plating with the special hardenable metal may be stopped after a wall thickness is attained (such as that of the layer represented by 20 in Figs. 4–5–6–7) which is sufficient to house the lands and grooves of the final product's bore. (This particular thickness will, of course, vary with the rifling requirements of the individual weapon part being made; e. g., it would be about 0.02 inch in the military type caliber .50 gun.) The master, with its partially formed barrel or liner plated therearound, may then be transferred to another bath containing a cheaper, more abundant metal, such as iron, and the plating process resumed until the barrel or liner acquires a further layer such as is represented by 21 in Figs. 6–7, and the barrel is thus built to its required total cross-sectional diameter.

In making gun barrels or liners of such composite electroplated coatings, caution must be observed in the selection of metals because of a possibility that cracking will occur when the product is later annealed, due to the differences in the various coefficients of expansion. For example, I have found that a layer of nickel, plated from a strong nickel chloride bath, could not be used over a cobalt or a cobalt-tungsten alloy for this reason. On the other hand, I have found that a good combination for such composite coatings consists of a cobalt-tungsten inner lining with the balance of the electroformed product made up of either cobalt or iron.

As an extra added precaution in assuring a strain-free final product, it has been found preferable to grind the outside wall surface of the barrel or liner being electroformed after a coating several hundredths of an inch thick has been deposited on the master 11 (compare unground product of Fig. 4 with ground product shown in Fig. 5). This procedure is helpful because the metal which plates on the master has a tendency to form a pattern duplicating the master's lands and grooves (see Fig. 4). Were the contours of those lands and grooves permitted to be thus "transmitted" throughout the entire electroformed product, lines of weakness between the lands and grooves would result. Grinding to eliminate the contours or pattern of the riflings (see Fig. 5) prevents this occurrence.

When the electroformed sheath or envelope (barrel 13 in the drawings) has been plated to a sufficient thickness to meet the requirements of the desired gun barrel or barrel liner (as in Fig. 6), master 11 is removed therefrom (resulting in the product shown by Fig. 7). This is done by heating the assembly to about 400° C. to melt and eliminate the lead coating 24, the master 11 then being easily extracted from the electroformed barrel 13 with the aid of the earlier described extractor 17. Preferably, prior to so heating the assembly, the handle 28 should be slidably removed from extractor 17, and plastic cap 27 should be slipped off the assembly. The other plastic cap 26 should likewise be removed, the purpose being to avoid the possibility of high temperatures damaging these masking aids. Of course, if the plastic or other masks used have a sufficiently high melting point they need not be removed prior to this heating step.

A further caution, which experience has shown to be valuable in practicing my invention, should

be observed in the actual process of extracting the master. In this extraction, the end of the electroformed barrel 13 that bears against the extractor 17 should be perpendicular to the axis of that barrel 13; otherwise the hot master 11 may be bent during its extraction.

After the electroformed barrel 13 has been freed from master 11, it may be heat treated to anneal the alloy from which the barrel 13 was made. The last step in my novel process is to machine or grind this electroformed barrel 13 to its final form in accordance with the various requirements for its overall diametral dimensions (which variance depends, among other things, on whether the product is to be used as a gun barrel or a separate reliner to be inserted into a barrel). This machining or grinding step can be done with standard machinery and, for purposes of mass production, can be readily processed with conventional centerless grinders.

The time required for my entire unique process as above described will of course vary with the thickness of the liner or barrel desired to be thus electroformed, and the metals from which those products are to be made. For example, the time required to plate a 0.02 inch thick coating of cobalt tungsten alloy (like the metal layer 20 shown in Figs. 1–4–5–6–7) for use as a gun liner in one typical instance was found to be about 24 hours when a current density of 2 amperes per square decimeter was used. The remainder of the electroformed liner envelope (similar to the metal layer 21 shown in Figs. 1–6–7) was made of cobalt which was plated on top of the cobalt-tungsten alloy at a minimum rate of 0.005 inch per hour.

In this specific example, an entire liner ⅛ inch thick, plus a margin for machining the outside wall surface, was plated in approximately three days. However, the actual time per unit product required of an operator during this operation was very low because a large number of liners were accommodated in the single plating bath, and they required no attention during the plating process.

It should be understood that the composition of the various alloys mentioned above is not critical in the practice of the present invention. That is to say, practically any alloy of cobalt and tungsten or cobalt and molybdenum may be utilized in the process hereinabove described, the sole determining criterion being the particular properties in the finished liner or barrel which is desired by those who practice my invention. However, for the purposes of illustration, suitable alloys now will be described by reference to one manner in which they may be made. These alloys, and more particularly a method and bath for electrodepositing them, are disclosed in co-pending patent applications of which I am a co-applicant.

In co-pending application Serial No. 708,566 which I filed on November 8, 1946, jointly with Polly S. Burkhead and Clara A. Sentel for "Method of and Bath for Electrodepositing Tungsten Alloys," there is described a bath which consists of 70 grams per liter sodium tungstate, 28 grams per liter cobalt chloride, 100 grams per liter Rochelle salt, 50 grams per liter ammonium chloride, and the remainder is made up of water plus sufficient ammonium hydroxide required to adjust the alkalinity of the bath. This bath is operated at a temperature of about 90° C., at a current density of 1 to 3 amperes

per square decimeter, and the pH is maintained between 8 and 9.

In co-pending application Serial No. 708,565 which I filed on November 8, 1946, jointly with Polly S. Burkhead for "Carbonate Electrolytic Bath and Methods for Electrodepositing Cobalt or Cobalt-Molybdenum Alloys Therefrom," there is described a bath which consists of 1000 grams per liter of potassium carbonate, 15 grams per liter of cobalt chloride or cobalt sulphate, 100 grams per liter of sodium molybdate, and the remainder is made up of water. This bath is operated at a temperature of between 90 and 135° C., at a current density of 1 to 5 amperes per square decimeter and a pH of 11.

All the aforementioned objects of my invention have been attained by means of the methods and alternative techniques earlier outlined. However, it will be obvious to anyone generally skilled in the art that my invention can be practiced in numerous other ways without departing from the spirit or scope of my discoveries.

My invention is therefore extensive in its adaptation and is not to be restricted to the specific form here shown by way of illustration.

I claim:

1. The method of manufacturing a gun barrel having a rifled bore out of metals that are highly resistant to erosion and corrosion but are too hard to machine or cast conveniently, which comprises making a steel "negative" form whose external dimensions substantially correspond to required internal dimensions for the desired gun barrel's rifled bore, polishing said "negative" form to a smooth finish, plating a thin layer of lead upon the outer surface of said "negative" form, thereafter electropolishing the lead-coated "negative" form to a bright and smooth finish, thereafter electroplating the metal from which said gun barrel is to be made to a desired part of the desired total thickness upon the outer surface of said lead-coated "negative" form at a temperature below the melting point of said lead coating, thereafter grinding smooth the outer surface of the metal which has been thus electroplated upon the lead-coated "negative" form in order to eliminate the contour of the underlying lands and grooves from the subsequent plating, thereafter resuming electroplating the metal from which said gun barrel is to be made as aforesaid until the desired total gun barrel thickness plus a margin for final machining has been reached, thereafter heating the thus electroplated "negative" form to a temperature high enough to melt and eliminate said lead coating from said "negative" form, thereafter extracting said "negative" form from the resultant gun barrel that has been electroformed therearound, and then grinding the outside wall surface of the resultant gun barrel to the desired overall cross-sectional dimensions.

2. The method of manufacturing a gun barrel having a rifled bore out of metals that are highly resistant to erosion and corrosion but are too hard to machine or cast conveniently, which comprises making a metallic "negative" form whose external dimensions substantially correspond to required internal dimensions for the desired gun barrel's rifled bore, polishing said "negative" form to a smooth finish, plating upon the outer surface of said "negative" form a thin layer of a fusible metal which does not readily alloy with the metal of the "negative" form, thereafter electropolishing the fusible metal-coated "negative" form to a bright and smooth finish, thereafter electroplating the metal from which said gun barrel is to be made to a desired part of the desired total thickness upon the outer surface of said fusible metal-coated "negative" form at a temperature below the melting point of said fusible metal coating, thereafter machining smooth the outer surface of the metal which has been thus electroplated upon the fusible metal-coated "negative" form in order to eliminate the contour of the underlying lands and grooves from the subsequent plating, thereafter resuming electroplating the metal from which said gun barrel is to be made as aforesaid until the desired total gun barrel thickness plus a margin for final machining has been reached, thereafter heating the thus electroplated "negative" form to a temperature high enough to melt and eliminate said fusible metal coating from said "negative" form, thereafter extracting said "negative" form from the resultant gun barrel that has been electroformed therearound, and then machining the outside wall surface of the resultant gun barrel to the desired overall cross-sectional dimensions.

3. The method of claim 2 in which the electroplated metal from which the gun barrel is to be made is selected from the group consisting of cobalt, cobalt-tungsten alloy, and cobalt-molybdenum alloy.

4. The method of claim 2 in which cobalt is the metal from which the gun barrel is to be made.

5. The method of claim 2 in which an alloy of cobalt-tungsten is employed as the metal from which the gun barrel is to be made.

6. The method of claim 2 in which an alloy of cobalt-molybdenum is employed as the metal from which the gun barrel is to be made.

ABNER BRENNER.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
602,212	Desolle	Apr. 12, 1898
850,912	Edison	Apr. 23, 1907
1,151,318	Wood	Aug. 24, 1915
1,412,174	Eustis et al.	Apr. 11, 1922

FOREIGN PATENTS

Number	Country	Date
12,264	Great Britain	of 1888
239,977	Great Britain	Sept. 24, 1925