May 6, 1969 R. F. WEHRMANN ET AL 3,442,172

GUN BARREL LINER

Filed March 13, 1959

Fig. 1

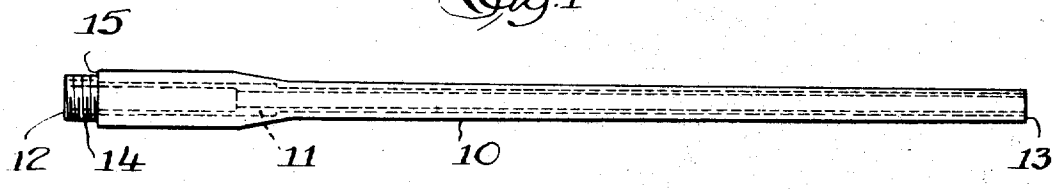


Fig. 2

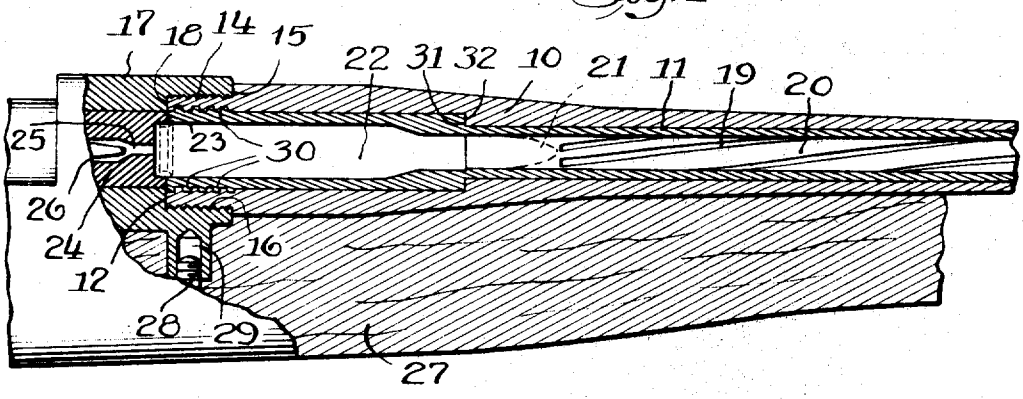
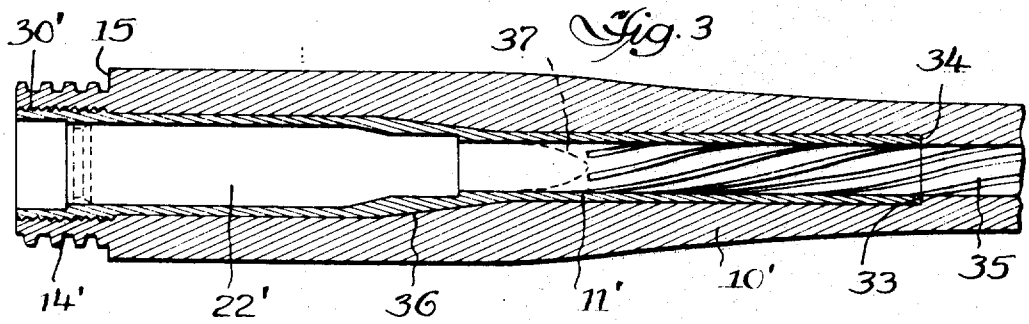


Fig. 3



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GUN BARREL LINER

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The present invention relates to barrel liners and a method of making the same. More particularly, the invention relates to barrel liners formed of columbium base metal and a method of making the liners and providing them with improved life qualities.

Heretofore, particularly in .30 caliber and .50 caliber rapid fire units such as machine guns, substantial difficulties have been experienced with the life of the barrel. Barrels have been made of steel or stellite with and without provision for liners. These barrels often had a life of less than 3500 rounds. After that number of rounds had been fired, the rifling in the barrel or in the barrel liner was so eroded or otherwise destroyed so that the projectiles "keyholed" and suffered substantial muzzle velocity losses with respect to projectiles fired when the barrel was new.

Previous attempts to overcome these difficulties have met with little success. These attempts included such techniques as vapor depositing a tantalum film on the interior of the barrel, and lining the barrel with punched, aligned molybedenum washers or discs. Neither of these techniques have proved successful. The vapor deposited film did not stand up under rigorous use, and the molybdenum discs oftend separated thereby destroying the effectiveness of the gun.

Barrel liners embodying the present invention, however, obviate all of these difficulties in that they have demonstrated lasting qualities and long life as well as resistance to corrosion, erosion and distortion.

Further, barrel liners embodying the present invention may be formed as full length liners or as fragmental length liners at the breech end of the gun barrel.

Gun barrel liners embodying the present invention are preferably formed of columbium or columbium alloys, hereinafter referred to as "columbium base metal," which term is intended herein to cover substantially pure columbium as well as columbium alloys.

In accordance with this invention the columbium base metal liner has a substantially tubular structure so that all or a selected portion of its length may be provided with rifling and so that it may be readily placed into a gun barrel or jacket of steel or other suitable material.

The columbium base metal of the liners, in accordance with this invention, are alloyed with oxygen preferably in the range of from about 0.15 percent by weight to about 0.55 percent by weight and the liners are annealed or otherwise heat treated whereby the oxygen-columbium base metal alloy liners have a hardness preferably in the range of from about Ra 40 to about Ra 70 as read on a Rockwell A scale. The hardness of the liner is an important consideration since the liner, if softer than about Ra 40, will distort thereby destroying the rifling or the effectiveness of the liner. At the other end of the scale, if the liner is too hard, it will be excessively brittle and will not be able to withstand the thermal and physical shocks and stresses that will be applied to it during firing of projectiles.

In accordance with the present invention, barrel liners may be made for assembly with a gun barrel and have a hardness within the aforementioned range, by forming a substantially tubular member of columbium base metal,

recrystallizing or annealing the member by heating it to a temperature above about 1000° C. preferably for a period of from about 15 minutes to about 120 minutes inversely with respect to the annealing temperature employed, alloying the columbium base metal member with oxygen in such a manner as, for example, electrolytically forming an oxide coating of the columbium base metal on the member at a current density in the range of from about 5 milliamperes per square inch of surface to about 20 milliamperes per square inch of surface being oxidized for a period of from about 2.5 hours to about 30 hours, in an oxygen bearing electrolyte such as, for example, an aqueous mixture of glycol and an appropriate organic acid, ammounium borate, and sulfuric acid, and heating the oxide coated member at a temperature preferably in the range of from about 1200° C. to about 1600° C. for a period greater than about .5 hour to cause penetration of the oxygen into the member and alloy the oxygen with the columbium base metal to harden the member to a hardness within the prescribed range therefor, and machining the tubular member.

It will be understood, of course, that the step of recrystallizing and annealing need not be effected preceding the oxygen alloying of the member and that the recrystallizing and annealing heat treatment may be effected as a part of the alloying heat treatment where recrystallization is desired.

In any event, barrel liners embodying the present invention should have a hardness of from about Ra 40 to about Ra 70 and are formed of a columbium base metal alloy with oxygen added in the range of from about 0.15 percent by weight to about 0.55 percent by weight.

In the accompanying drawings which form a part of this specification, there are shown illustrative embodiments of this invention in the form of a liner for the barrel of a .30 caliber gun and in the form of a liner for a barrel of a .50 caliber gun. In the drawings, like reference numerals refer to like parts of the illustrative embodiments therein shown, and:

FIGURE 1 is an elevational view of a gun barrel with a full length liner therein embodying this invention;

FIGURE 2 is a longitudinal sectional view of a barrel liner for a .30 caliber gun in place in the barrel thereof and mounted on an exemplary form of stock; and

FIGURE 3 is a longitudinal sectional view of a fragmental liner in place in a .50 caliber gun barrel.

It will be appreciated, of course, that while FIGURE 2 illustrates a full length liner in a .30 caliber bun barrel and FIGURE 3 illustrates a fragmental length liner in a .50 caliber gun barrel, either size of gun barrel as well as any other desired size gun barrel, may be fitted with either a full length liner or a fragmental length liner embodying this invention, as desired. It should be understood also that barrel liners embodying the present invention are of general utility and that the forms of the invention shown in the accompanying drawings and described in detail hereinbelow are only illustrative embodiments of the invention and that the invention is not limited thereto.

The gun barrel **10** shown in FIGURE 1 is a typical barrel for use with the gun mechanism of a .30 caliber or a .50 caliber automatic or semiautomatic gun mechanism. In accordance with this invention, the barrel is provided with a liner **11** which is a full length liner extending from the breech end **12** of the barrel to the muzzle end **13** of the barrel. The liner is secured, preferably at least at the breech end **12** of the barrel, by any convenient means such as a threaded connection or a slotted flange connection. The barrel and liner, however, may be

assembled by any convenient means. An example of this might be to place an unrifled liner in a slightly oversize barrel and draw or swedge the barrel and liner simultaneously to provide rifling lands and grooves in the liner and to assemble the barrel and liner and secure the same together.

The assembled barrel and liner may be secured onto the mechanism of the gun by any convenient means such as a threaded portion **14** provided with a stop shoulder **15** at the breach end of the barrel.

As shown in FIGURE 2, the threaded end **14** of the barrel **10** interfits with a threaded recess **16** in the head **17** of the gun mechanism. The head **17** is provided with a stop face **18** which is disposed at a distance within the head which corresponds to the distance of the stop shoulder **15** from the breech end **12** of the barrel so that the faces **15** and **18** provide cooperative locking stop shoulders for assembly of the barrel on the head **17**.

The liner **11** is a substantially tubular member provided with rifling lands **19** and grooves **20** in at least the portion of the liner ahead of the projectile shown by dashed lines **21**, toward the breech end of the liner. The liner is provided with a head space **22** to receive the cartridge or casing for the projectile and is shaped to properly receive and seat the cartridge for proper firing of the projectile.

The breech end **23** of the liner **11** is substantially flush with the breech end **12** of the barrel so that the bolt **24** or other cartridge backing member of the gun mechanism in the head **17**, will seat thereagainst for holding the cartridge in place. The bolt **24** is provided with an axial bore **25** to receive the firing pin **26** for movement therein to strike the cartridge to cause firing thereof.

In the embodiment of the invention shown in FIGURE 2 the head **17** and the barrel **10** with the liner **11** therein are mounted on a mounting member **27** such as a wooden stock or other desired member. The head **17** may be locked in place by any appropriate means such as a screw **28** received in a threaded recess **29** therein and passing through an opening in the mounting member.

The liner **11** is secured to the barrel **10** by a plurality of square threads **30** within the barrel at **10** the breech end thereof and underlying the mounting threads **14** for the barrel **10**. The liner and the barrel are provided with cooperating shoulders **31** and **32** so the liner may be threaded into the barrel along the threads **30** until the shoulders **31** and **32** mate for proper seating of the barrel.

As discussed above, the liner may be secured within the barrel in any desired way in accordance with this invention. It is desirable, however, that the liner be secured to at least a breech end of the barrel so that differences in thermal expansion and in elongation of the liner and the barrel can be accommodated at the muzzle end of the gun thereby preventing distortion of the head space **22** in the liner. It is desirable to prevent distortion of the head space **22** so as to maintain a close fit between the cartridge and the liner thereby reducing the possibilities of misfiring or, even worse, backfiring.

The embodiment of the invention shown in FIGURE 3 is similar to that of FIGURE 2 except that the liner **11'** is a fragmental length liner, the forward end **33** of which abuts a shoulder **34** in the rifled barrel passage **35**. Inasmuch as the end **33** of the liner abuts a shoulder **34** in the barrel passage **35**, the shoulders **31** and **32** of the liner **11** in FIGURE 2 have been replaced by a tapered interfit **36** in the region of the junction between the projectile shown by dotted line **37** and the cartridge casing in the head space **22'**. It will be appreciated, of course, that the shoulder interfit type of stop for the liner shown in FIGURE 2 at **31** and **32** may be employed with a fragmental length liner of the type shown in FIGURE 3.

The remainder of the mounting of the liner **11'** in the barrel **10'** of FIGURE 3 is substantially the same as that shown in FIGURE 2 excepting that in the embodiment of FIGURE 3, the barrel has been shown with substantially square threads **14'** leading to a shoulder **15'**, and the liner

is threaded into the breech end of the barrel and secured by the threads **30'**. Either type of threading or any other type of securement between the barrel and the liner at the breech end thereof may be used interchangeably in any desired manner as expediency or necessity may dictate.

The embodiments of the invention shown in FIGURES 1, 2 and 3 are illustrative only since any other desired form, configuration or size of gun barrel and liner may be employed embodying this invention. Also, other techniques, such as swedging and shrink fitting, may be employed to secure the liner within the barrel.

The barrel liners of FIGURES 1, 2 and 3, in accordance with this invention, were made of columbium base metal. Columbium stock is usually made by sintering or melting processes which render the metal relatively ductile and soft. If a gun barrel liner is made of such soft metal, the lands and grooves therein will be destroyed relatively rapidly and the metal will distort thereby destroying the effectiveness of the liner. In accordance with this invention, however, these problems are overcome by alloying the columbium base metal with oxygen in the range of from about 0.15 percent by weight to about 0.55 percent by weight and heat treating the alloy to provide the same with a hardness as read on a Rockwell A scale, of from about Ra 40 to Ra 70.

The following are two examples of the method of the present invention as utilized for the manufacture of gun barrel liners embodying this invention.

Example I

Columbium base metal stock consisting essentially of columbium metal with incidental impurities and zirconium in an amount of about 1.35 percent, formed by pressing and sintering metal powder, was worked mechanically into a substantially tubular form.

The member was then cleaned and disposed in an electrolytic tank and submerged in an electrolyte of an aqueous solution of glycol and an appropriate organic acid. Other electrolytes such as ammonium borate or sulfuric acid may be employed here. While so submerged, the tubular member was subjected, as the anode of the electrolytic arrangement, to a current density of about 14 milliamperes per square inch of exposed surface area for a period of about 10 hours to anodically form an adherent columbium base metal oxide film on the member. The current density may vary from about 5 milliamperes per square inch to about 20 milliamperes per square inch and the anodic treatment may run for a period of from about 2.5 hours to about 30 hours.

The member was then removed from the tank and washed. By weighing the member before and after the anodic treatment thereof, it was determined that the member had a weight gain due to the addition of oxygen thereto of about 0.40 percent.

Following the electrolytic oxidizing step, the member was reinserted in the furnace and heated to a temperature in the range of 1350° C. to 1570° C. for a period of about 2 hours to cause effective penetration of the oxygen of the film into the member and thereby alloy the oxygen with the columbium base metal. This oxygen penetration heat treatment may be carried out at a temperature in the range of from about 1200° C. to about 1600° C. for a period greater than about .5 hour. The longer the time at which the member is held at temperature, the deeper and more effective the penetration and alloying of the oxygen from the film will be.

After the oxygen penetration and alloying heat treatment, the member was tested for hardness and found to have an average hardness of about Ra 62 as read on a Rockwell A scale.

Subsequently, the tubular member was machined and finished and disposed in assembly with a .30 caliber machine gun barrel as a full length liner therein. Standard testing was effected and after 5645 rounds testing was

stopped since it did not appear that further testing was necessary inasmuch as the barrel liner had already demonstrated its outstanding performance, life and erosion resistance quality. At 5645 rounds there was substantially no keyholing of projectiles fired from the gun and the muzzle velocity loss with respect to the first rounds fired was only about 78 feet per second. The liner in this instance had a thickness in the range of from about 0.050 inch to about 0.065 inch and the rifling depth was about 0.004 inch.

The initial testing of the liner was a 426 round standard test wherein the following schedule was observed:

(1) One high pressure proof round was fired.
(2) One 25 rounds burst was fired.
(3) Two 50 rounds bursts were fired.
(4) One 100 rounds burst was fired.
(5) One 200 rounds burst was fired.

After each burst was fired the target was examined and the barrel and the liner were examined. Also, the recording instruments determining muzzle velocity were examined. There was no apparent erosion or corrosion of the barrel liner, there was no keyholing of the projectiles and there was substantially no muzzle velocity loss.

Following the 426 rounds test, 125 rounds bursts were fired until 5645 rounds had been fired and testing was stopped.

Example II

The barrel liner of this example was made by substantially the same method and in substantially the same way as the barrel liner of Example I. In this example, however, the liner was annealed and recrystallized prior to oxygen alloying. To effect annealing, the tubular member was placed in a furnace and heated in a vacuum to a temperature of from 1300° C. to 1415° C. for a period of about 1 hour after which it was permitted to cool slowly to room temperature in the vacuum. A protective atmosphere of helium and/or argon may be substituted for the vacuum. This annealed the tubular member and caused recrystallization thereof. The annealing may be carried out at temperatures above about 1000° C., preferably for a period of from about 15 minutes to about 120 minutes. The temperature and time, of course, for effective recrystallization are interrelated as reciprocal functions so that higher temperatures employed for recrystallization requires less recrystallization time and vice versa.

The oxygen alloyed with the columbium base metal of the liner was 0.22 percent and the liner had an average hardness of Ra 63.5 as read on a Rockwell A scale. The columbium base metal was an alloy of oxygen with about 40 percent tantalum and remainder substantially all columbium.

This barrel liner was tested by firing, after a first high pressure proof round, successive 20 rounds bursts every 14 seconds until testing was stopped after the firing of 3500 rounds. It was found at the conclusion of testing that the muzzle velocity increased by two feet per second but that 50 percent of the projectiles fired from the barrel after 3000 rounds were keyholing. Examination of the barrel and liner revealed that the keyholing was due to erosion of the steel at the muzzle end of the barrel, but that the liner was still in good condition and that the 3500 rounds test had not had a substantial detrimental effect on the condition of the liner.

The .50 caliber barrel liners which were tested had a thickness of from about 0.050 inch to about 0.075 inch and a rifling depth of about 0.006 inch.

Numerous other barrel liners were made and tested and it was found that the hardness of the liner, as measured on a Rockwell A scale, should be in the range of from about Ra 40 to about Ra 70 and that the oxygen content of the alloy for the liner should be in the range of from about 0.15 percent by weight to about 0.55 percent by weight.

From the foregoing it will be readily observed that numerous modifications and variations may be effected without departing from the true spirit and scope of the novel concepts and principles of this invention.

We claim:

1. A liner for a gun barrel and to be secured within the gun barrel, comprising a substantially tubular member of columbium base metal having a hardness as read on a Rockwell A scale substantially in the range of from about Ra 40 to about Ra 70, said member of columbium base metal being formed of an alloy with oxygen, the oxygen added to the columbium base metal in the alloy being present in the range of from about 0.15 percent by weight to about 0.55 percent by weight.

2. A liner for a gun barrel and to be secured within the gun barrel, comprising a substantially tubular member of columbium base metal having a hardness as read on a Rockwell A scale substantially in the range of from about Ra 40 to about Ra 70, said member of columbium base metal being formed of an alloy with about 40 percent by weight of tantalum therein, and with oxygen, the oxygen added to the columbium base metal in the alloy being present in the range of from about 0.15 percent by weight to about 0.55 percent by weight, whereby the member has a hardness within the predetermined range therefor.

3. A liner for a gun barrel and to be secured within the gun barrel, comprising a substantially tubular member of columbium base metal having a hardness as read on a Rockwell A scale substantially in the range of from about Ra 40 to about Ra 70, said member of columbium base metal being formed of an alloy with oxygen, the oxygen added to the columbium base metal in the alloy being present in the range of from about 0.15 percent by weight to about 0.55 percent by weight, and impurities including zirconium present in the alloy in an amount of about 1.35 percent by weight, whereby the member has a hardness within the predetermined range therefor.

4. In a gun barrel and liner in combination wherein the gun barrel and the liner are secured together, said liner being formed of a tubular member distinct from the barrel and constructed of hardened columbium base metal having a hardness substantially in the range of from about Ra 40 to about Ra 70 and having oxygen added to and alloyed with the columbium base metal in the range of from about 0.15 percent by weight to about 0.55 percent by weight.

5. In a gun barrel and liner in combination wherein the gun barrel and the liner are secured together, said liner being formed of a tubular member distinct from the barrel and constructed of hardened columbium base metal having a hardness as read on a Rockwell A scale substantially in the range of from about Ra 40 to about Ra 70, said member of columbium base metal being formed of an alloy with about 40 percent by weight of tantalum therein, and with oxygen, the oxygen added to the columbium base metal in the alloy being present in the range of from about 0.15 percent by weight to about 0.55 percent by weight, whereby the member has a hardness within the predetermined range therefor.

6. In a gun barrel and liner in combination wherein the gun barrel and the liner are secured together, said liner being formed of a tubular member distinct from the barrel and constructed of hardened columbium base metal having a hardness as read on a Rockwell A scale substantially in the range of from about Ra 40 to about Ra 70, said member of columbium base metal being formed of an alloy with oxygen, the oxygen added to the columbium base metal in the alloy being present in the range of from about 0.15 percent by weight to about 0.55 percent by weight, and impurities including zirconium present in the alloy in an amount of about 1.35 percent by weight, whereby the member has a hardness within the predetermined range therefor.

(References on following page)

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References Cited

UNITED STATES PATENTS

2,820,399	1/1958	Comenetz	89—16
2,849,923	9/1958	Cotterman	89—16
1,167,233	1/1916	Warner	29—1.1
2,104,319	1/1938	Dicke	29—1.1
2,373,405	4/1945	Lowit.	
2,609,631	9/1952	Garand	89—16

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2,860,970	11/1958	Thielemann	75—174
2,883,282	4/1959	Wainer	75—174

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