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.

This invention relates to gun barrels in which the rifled bore is located in a liner fabricated from a different metal than the supporting tube and to methods for fixing the liner within the tube and forming the rifling in the liner.

With modern types of modern guns, the metals from which the barrels are fabricated are not sufficiently resistant to the heat and wear produced by rapid and long bursts of fire to prevent mutilation of the rifling. Consequently, it is necessary to protect the rifled bores with claddings of other metals to form the rifled bores of liners fabricated from refractory metal and fix the liner within the supporting tube.

Explorations of the characteristics and utilities of such exotic metals as columbium, tantalum, molybdenum, beryllium, zirconium and tungsten have been initiated during recent years and it has been found through these explorations that these refractory metals, which have melting points much higher than steel, retain their hardness at high temperatures and retain their ductility after being worked. Alloys of these metallic elements, therefore, are ideally suited for cladding the rifled bores of gun barrels or making the rifled liners.

Trouble, however, has been encountered heretofore in the utilization of these metals for liners having relatively thick walls of the order of .025-.046 inch. The difficulty arises because of the considerable difference between the coefficient of expansion of these refractory metals and those of steel, aluminum and titanium from which the supporting tube is fabricated.

It is noted that the coefficient of expansion of steel per degree at 68°F is around 6.8×10⁻⁶, depending upon the alloy; that of aluminum alloys is around 12.7×10⁻⁶; and titanium, 5.0×10⁻⁶. On the other hand, the coefficient of expansion of columbium is 4×10⁻⁶; tantalum, 3.6×10⁻⁶; molybdenum, 2.7×10⁻⁶; and tungsten, 2.4×10⁻⁶.

The temperature of gun barrels oftentimes reaches 1400°F to 1500°F, and it is obvious from the above noted figures that at this temperature the tubes expand considerably more than the liners and that with relatively long barrels the difference in the expansions of the expansions of the tube and a liner having relatively thick walls is considerable. It is also obvious that, during the intermittent bursts of fire to which gun barrels are subjected, the cyclic expansion and contraction of the tube and liner would disturb the permanent relationship thereof and cause faulty function of the barrel.

It is, therefore, one object of this invention to provide a barrel in which a liner of refractory metal is fixed within a tube of steel, aluminum or titanium alloy so as to allow for the difference between the coefficients of expansion of the liner and tube.

It is another object of this invention to provide a barrel in which such a liner of refractory metal is fixed within the supporting tube so as to permit relative expansion of the liner and tube without disturbing the relationship between the cartridge chamber in the tube and the adjacent end of the liner.

It is a further object of this invention to provide such a barrel in which the liner is anchored within the tube at the section which is adjacent the breech end of the barrel.

It is still another object of this invention to provide such a barrel in which the difference between the longitudinal expansion of the tube and liner during firing is concentrated towards the front ends thereof and in which the hole provided in the tube for accommodating the liner is hardened to resist wear due to relative displacement of the liner and tube.

It is still another object of this invention to provide a method of fabricating such a barrel, wherein the liner is anchored to the tube at the rear end, means for uniformly distributing the differential forces which are produced in the barrel between the front and rear ends because of the differences in the expansion of the tube and liner.

It is another and still further object of this invention to provide a method of fabricating such a barrel whereby the liner is anchored to the tube, the liner is rifled, the area of the tube surrounding the liner is hardened, and the overall dimensions of the barrel are brought to size simultaneously by the same operation.

The specific nature of the invention as well as other objects and advantages thereof will clearly appear from a description of a preferred embodiment as shown in the accompanying drawings in which:

FIG. 1 is a partially cross-sectional side view of the barrel;

FIG. 2 is a view taken along line 2—2 of FIG. 1;

FIG. 3 is a view taken along line 3—3 of FIG. 1;

FIG. 4 is a fragmentary and partially cross-sectional side view of the billet, the tubular blank for the liner, and the mandrel for forming the bore size of the liner and the rifling therein;

FIG. 5 is a longitudinally cross-sectional view of the barrel during the forming process and the means for forming the barrel design dimensions and simultaneously anchoring the liner to the tube and forming the rifling in the liner bore;

FIG. 6 is a view taken along line 6—6 of FIG. 5; and

FIG. 7 is an enlarged fragmentary view similar to FIG. 6.

Shown in the figures is a gun barrel 12 composed of a tube 14 and a liner 16. Tube 14 may be fabricated from steel or from such light metals as aluminum and titanium and is provided with a cylindrical hole 18 which extends axially forward therethrough from a cartridge case chamber 20 formed in the rear end of the tube. Liner 16, which is received by hole 18 and is anchored to tube 14, as hereinafter described, is fabricated from an alloy selected from such refractory metals as columbium, tantalum, molybdenum, tungsten, zirconium and beryllium which have melting points higher than that of chromium and which retain their hardness at high temperatures. An alloy composed of 90% tantalum and 10% tungsten has proven effective because of its favorable work hardening properties, ductility even at extremely low temperatures and high modulus of elasticity.

Liner 16 is provided with an axial bore 22, which is rifled as noted at 24, and provided around the outside of the liner at the rear end thereof, which is adjacent chamber 20, are three longitudinally spaced annular grooves 26 in which mating ribs 28 integrally extending from the wall of hole 18 are embedded. Grooves 26 are arranged normal to the longitudinal axis of the liner 16. Extending forwardly of grooves 26 in the outside of liner 16 is a pair of helical channels 30 which progress forwardly similarly in opposite directions so as to cross at diametrically opposed points in the liner. A mating pair of beadings 32 extend integrally from the wall of hole 18 to fill channels 30 along the lengths thereof.
As noted at section 34, channels 30 start to fade out to blend with the outside surface of liner 16 approximately midway the length thereof so that about one-third thereof at the front end is uninterrupted as noted at section 36. Consequently, headings 32 similarly fade out to blend with the wall of hole 18 as noted at section 38.

At atmospheric temperatures, liner 16 is compressibly gripped by the wall of hole 18. But under the increased temperatures produced by firing and because of the difference in the coefficients of expansion of the metals from which tube 14 and liner 16 are fabricated, the length of the tube is increased relative to that of the liner and the radial force with which the liner is gripped by the tube is decreased. However, liner 16 remains fully supported by tube 14 because a part of the difference between the coefficients of expansion of the metals thereof is compensated for by the difference between the temperatures thereof as the temperature of the liner during firing is considerably greater than that of the tube. In addition, the compressive forces which are set up in tube 14 and liner 16 during the forming operation, to be hereinafter described, and the ductility of the metals in the tube and liner also assist in maintaining supporting contact between the tube and liner.

It is very important that the relationship between the rear end of liner 16 and chamber 20 is not disturbed by the difference in the expansion of tube 14 and the liner. This is because the cartridge bullet seat is formed in bore 22 of liner 16 so that the neck of a cartridge case in chamber 20 extends therein and the necks must always extend into the liner during firing so that tube 14 will be protected from the flame which jets from the cartridge case at discharge.

Relative displacement of liner 16 and tube 14 at the rear ends is prevented by the resistance of headings 32 and ribs 28 to shearing. Ribs 28 in cooperation with grooves 26 resist relative longitudinal displacement of the rear section of tube 14 and liner 16. Having the pair of helical headings 32 turn in opposite directions, the headings in cooperation with channels 30 resist the torque produced in liner 16 as the cartridge projectiles are engraved by rifling 24 during passage along bore 22.

Section 36 of liner 16 and the front section of tube 14 are only in frictional contact and this is overcome by the forces of expansion to permit relative displacement therebetween. The portions of tube 14 and liner 16, which are in fixed engagement, are limited to about one-half the length thereof. The difference in the coefficients of expansion of tube 14 and liner 16 at these portions is compensated for by the elasticity thereof so that the relationship between the tube and liner is not permanently disturbed. As grooves 26 at the rear end of liner 16 and ribs 28 in tube 14 are arranged in planes normal to the longitudinal axis of the tube and liner, any temporary displacement therebetween by expansion forces is substantially nonexistent. Fading sections 34 and 38 of channels 30 and headings 32, respectively, serve to uniformly distribute the forces between the anchored rear portions of tube 14 and liner 16 and section 36 thereof and the front section of the tube because of the forwardly diminishing resistance of the headings to displacement between the tube and liner.

Moreover, by the forming method, to be hereinafter described, the area of tube 14 around hole 18 is worked hardened so that the wall of the hole is resistant to wear by the cyclic, relative displacement of the tube and liner 16.

Thus, in barrel 12, a liner 16 of refractory metal is successively incorporated into a supporting tube of steel or the lighter metals by fixing the liner to the tube so as to compensate for the difference between the coefficients of expansion of the metals thereof and so that the rear end of the liner has a fixed relationship with the cartridge case chamber located in the tube.

Barrel 12 is formed by the cold forming process according to the method outlined hereinafter so that, during a single operation, tube 14 is dimensioned to size, both as to diameter and to length; headings 32 and ribs 28 are formed from the wall of hole 18 and embedded in channels 30 and grooves 26, respectively; the area of the tube around such hole is work hardened; and rifling 24 is formed in bore 22.

During this cold working process, a billet 40, from which tube 14 is to be formed, is placed in a cold forming machine 42 which includes a power rotated chuck 44 for gripping one end of the billet and imparting rotation thereto. Chuck 44 is also adapted for actuating a hammer bed (not shown) parallel to the axis of billet 40 so as to draw the billet between a set of four hammers 46. Hammers 46 are spaced equidistantly 90° apart and are provided with working faces 48 which are concavely formed to conform to the design radius of tube 14. Hammers 46 are arranged for rapid actuation and with sufficient impact force to transform the metal of billet 40 to its plastic state.

This cold forming process reduces the diameter of billet 40 to the design dimension and flows the metal forwardly towards the front end. Therefore, the outside diameter of billet 40 is approximately 5% larger than the design diameter of tube 14. This will provide the required 5% elongation of billet 40 so that the length thereof before being worked is arranged so that with this elongation tube 14 is brought to design length.

Before billet 40 is mounted in cold working machine 42, cartridge case chamber 20 is machined to rough dimensions in the rear end thereof, which is gripping by chuck 44, and a tubular blank 50, from liner 16 is to be formed, is located in an axial aperture 52 provided axially through the billet from such chamber so that the rear end of the blank is contiguous thereto. In order to maintain the rear end of blank 50 in position relative to cartridge case chamber 20 prior to starting the cold forming process, the rear end is swaged sufficiently outward to make frictional contact with the wall of aperture 52. Prior to installation of blank 50 in billet 40, grooves 26 and channels 30 are machined in the outside surface of the blank.

When barrel 12 is for a .30 caliber machine gun, the thickness of the wall of blank 50 is approximately .025 inch and for larger calibers the wall is proportionately thicker. As billet 40 passes through hammers 46, the wall of the billet is compressed against blank 50 so that the metals of the billet and blank are transformed to their plastic states and are flowed forwardly. The diameter of blank 50 is reduced about 6% and the blank is elongated approximately 30% by the cold working process and, consequently, the length and diameter of the blank allow for these changes in dimensions.

Cold forming machine 42 also includes a cylindrical mandrel 54 which is coaxially fixed to the free end of a shaft 56 that extends longitudinally forward from a support (not shown) on the machine so that the mandrel is slidingly received by blank 50. Mandrel 54 is arranged to be coaxially located in the same vertical plate as hammers 46 so as to cooper therewith in forming barrel 12.

The outside diameter of mandrel 54 is the same as the diameter of bore 22 between the grooves of rifling 24 and machined in the outside surface of the mandrel are helical grooves 58 which conform to the dimensions and helix of the lands of the rifling.

Thus, as billet 40 is moved under hammers 46, it is compressed and transformed to the plastic state, and blank 50 is similarly transformed and compressed into contact with mandrel 54. At the same time, the metal of billet 40 is flowed into channels 30 and grooves 26 to form headings 32 and ribs 28 and the metal of blank 50 is flowed into grooves 58 in mandrel 54 to form the lands of rifling 24. As billet 40 is moved longitudinally, it is also rotated so that rifling 24 is formed according to the design helix. With this cold working process, the compressive forces set
up in billet 40 become residual compressive stresses in tube 14 to improve the supporting functions thereof and the cross-sectional area of the tube around hole 18 is work hardened by the repeated impacts of hammers 46 and the anvil functions of mandrel 54.

From the foregoing, it is clearly evident that this method provides a quick, simple but positive way of lining a rifle tube with a liner of refractory metal and bringing the barrel to design dimensions, and inducing desirable stresses therein.

Although a particular embodiment of the invention has been described in detail herein, it is evident that many variations may be devised within the spirit and scope thereof and the following claims are intended to include such variations.

1. The method of fabricating a gun barrel having a liner with a rifled bore and a supporting tube, the method including the steps of forming channels in the outside surface of a tubular blank from which the liner is to be formed so as to be angular to the longitudinal axis of the blank, inserting the blank within an axially bored cylindrical billet from which the tube is to be formed, inserting within the blank a mandrel having an outside diameter similar to that of the design bore of the liner and grooves corresponding to the design configuration and dimensions of the rifling lands of the bore, subjecting the billet at the area in which the mandrel is located to impacting hammers for radially compressing the billet against the blank and the blank in turn against the mandrel and for converting the metal of the blank and billet to their plastic states and flow the metal of the billet into the channels in the blank and the metal of the blank into the grooves of the mandrel, and moving the billet longitudinally and rotatingly relative to the mandrel and hammers to flow the metals of the billet and blank forwardly to simultaneously form the tube and liner, and the rifled bore therein, according to design dimensions.

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RICHARD H. EANES, JR., Primary Examiner.

BENJAMIN A. BORCHELT, Examiner.