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[54] **METHOD OF PRODUCING STEEL CYLINDER BARRELS HAVING BONDED BRONZE VALVE PLATES**

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[73] Assignee: **General Signal Corporation**

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[52] **U.S. Cl.** **29/527.6,** 29/473.3, 92/169, 164/76, 164/80, 164/112

[51] **Int. Cl.** **B23k 19/00**

[58] **Field of Search**....29/527.6, 473.3, 474.3, 474.4, 29/DIG. 8; 164/76, 80, 112; 92/169

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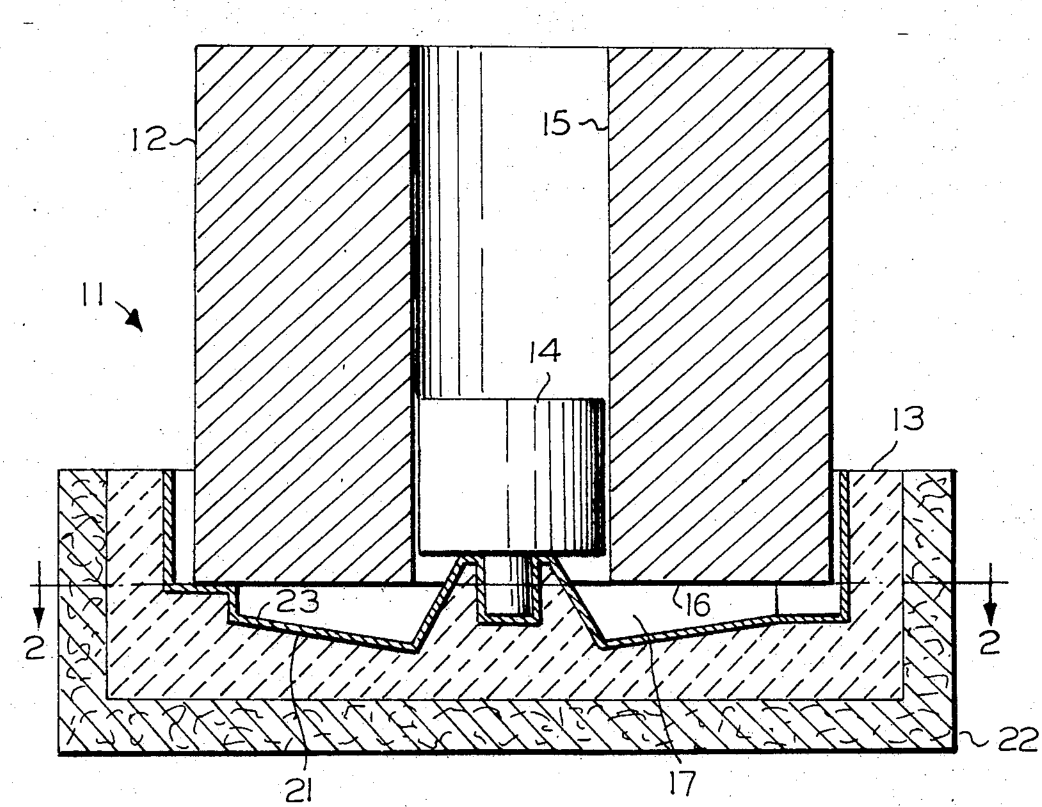
[57] **ABSTRACT**

The disclosure concerns a process for providing the steel cylinder barrel of a piston pump or motor with an adherent, bronze valve plate. The finished valve plate is machined from a bronze member which is cast in place against one end of the cylinder barrel blank under conditions which effect a sound metallurgical and mechanical bond between the steel and the bronze.

8 Claims, 4 Drawing Figures



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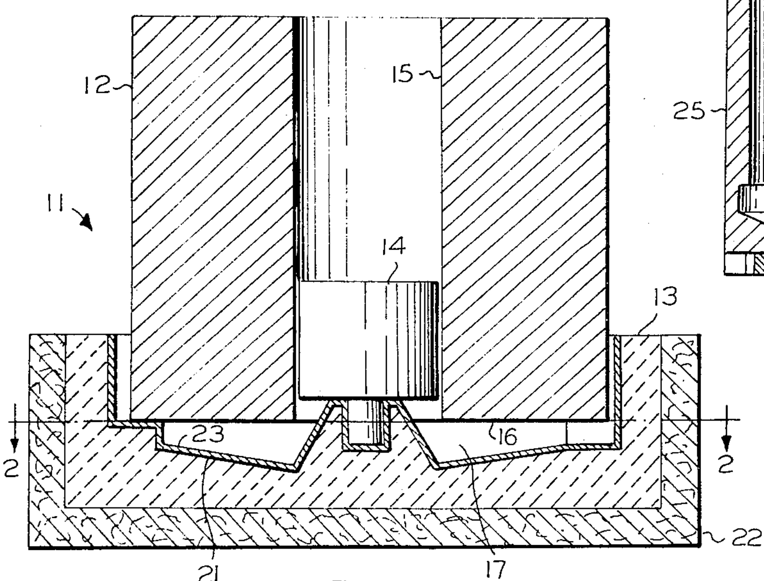

FIG.1

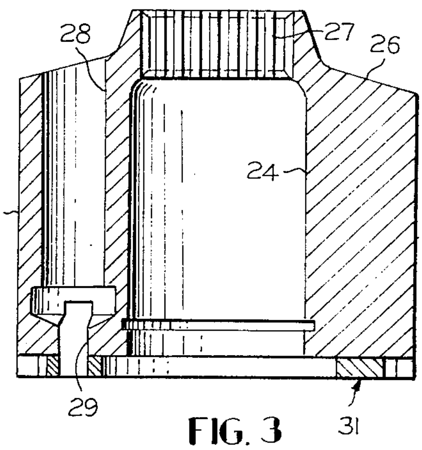

FIG. 3

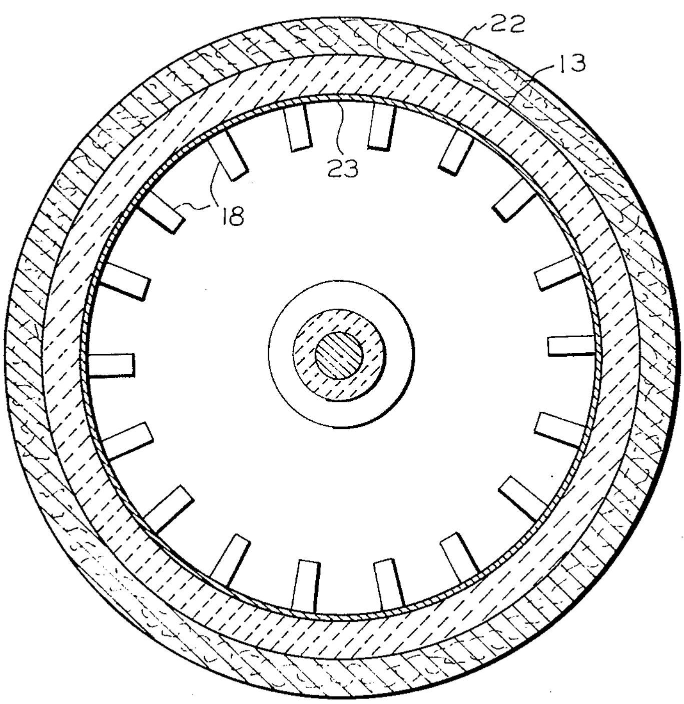

FIG.2

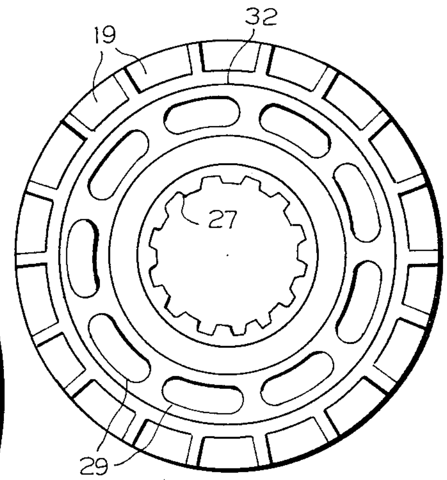

FIG.4

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METHOD OF PRODUCING STEEL CYLINDER BARRELS HAVING BONDED BRONZE VALVE PLATES

BACKGROUND AND SUMMARY OF THE INVENTION

In hydraulic pumps and motors of the rotary cylinder barrel, longitudinally reciprocating piston type, oil usually is transferred to and from the cylinder bores through a rotary valve at one end of the cylinder barrel. This valve comprises a stationary element containing arcuate high and low pressure ports which subtend angles slightly less than 180°, and an element which rotates with the cylinder barrel and contains a circular series of small arcuate ports, each of which communicates with one of the cylinder bores in the barrel. Since the valving elements are in continuous sliding engagement with each other during operation, it is desirable, if not a practical necessity in the case of high speed, high pressure hydraulic units, to make one of the two elements of bronze. This arrangement can be incorporated in several ways, but it is evident that the best approach for units which employ steel cylinder barrels is to use a bronze rotary valving element and to bond it directly to the end of the cylinder barrel. However, use of this design has been limited by the lack of a satisfactory process for producing a bond between the steel and the bronze.

The object of this invention is to provide a practical and reliable process for producing an adherent bronze valve plate on the valving end of a steel cylinder barrel. According to the invention, the new process is characterized initially by the formation of an assembly including a steel cylinder barrel blank, a mold which receives the valving end of the barrel and is shaped to define with an annular end face thereon a cavity in which a rough valve plate is to be cast, and a charge of bronze in the solid state which is adapted to flow into and fill the cavity when melted. The assembly is heated in a non-oxidizing atmosphere to a temperature between 1,900° and 2,000°F to melt the bronze charge, effect filling of the mold cavity, and to produce an intimate bond between the bronze and the steel end face of the cylinder barrel. Thereafter, the assembly is cooled in the controlled atmosphere to solidify the bronze and then air cooled to room temperature. Finally, the finished valve plate is machined from the rough cast bronze plate. This procedure creates a true metallurgical, as well as a mechanical, bond between the bronze valve plate and the steel cylinder barrel, and the shape of the mold cavity and the cooling rate of the cast bronze member are controlled so that shrinkage, if any, occurs in a region of the casting which is subsequently machined away. The combined effect of these factors makes the process a practical and reliable production technique.

BRIEF DESCRIPTION OF THE DRAWING

The preferred process is described herein in detail with reference to the accompanying drawing in which:

FIG. 1 is an axial sectional view of the barrel blank-mold-bronze charge assembly as it appears prior to the heating cycle.

FIG. 2 is a sectional view taken on line 2—2 of FIG. 1.

FIG. 3 is an axial sectional view of the finished cylinder barrel.

FIG. 4 is a view of the valving face of the finished cylinder barrel shown in FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The initial step of the preferred process concerns formation of the assembly **11** (see FIG. 1) which includes a steel cylinder barrel blank **12**, a mold **13** and a bronze charge **14**. Blank **12**, which is rough machined from SAE 52100, 1045 or 4150 steel stock, has a circular cross section, contains a through axial bore **15**, and is provided with a flat annular end face **16** to which the bronze valve plate is to be bonded. Face **16** is left in the rough turned state, since surface irregularities aid, rather than hinder, the bonding process. Moreover, it has been found that the process is not adversely affected by the formation of rust on fact **16**. After machining, blank **12** is cleaned to remove chips and then vapor degreased. Degreasing is not essential because any adherent oil or grease film will be burned off before the bronze-steel bond is effected. However, since these volatiles may leave a residue on face **16** which could cause localized impairment of the bond, it is considered best to remove them initially.

Mold **13** is formed to receive the end of blank **12** and to cooperate with face **16** to define a mold cavity **17**. The outermost region of cavity **17** is subdivided by a circumferential series of uniformly spaced, radial ribs **18** which define the dynamic bearing pads (see pads **19** in FIG. **4**) of the finished valve plate. Inboard of these ribs, the bottom wall **21** of cavity **17** slopes downward toward the center so that the thickest portion of the bronze casting will lie adjacent the inner periphery of face **16**. This arrangement is important because it enables the central portion of the casting to act as a "riser" and concentrate shrinkage in a region which is removed during final machining of the cylinder barrel. Because mold **13** usually has a relatively large surface area and low mass compared to blank **12**, it tends to cool much more rapidly than the blank. This differential cooling can cause shrinkage in the region of the bronze-steel interface and adversely affect the bond. In order to prevent this, mold **13** is equipped with a heat-insulating jacket **22** composed of a mass of asbestos fibers. Inclusion of the jacket tends to equalize the rates at which heat is transferred from the bronze through blank **12** and through mold **13**, and thus minimizes the risk of shrinkage at the bronze-steel interface. Mold **13** preferably is made of ceramic material and carries a thin graphite coating **23** which serves as a release agent for the casting, but carbon molds or graphite-coated steel molds may be used. It also is possible to make the mold of core sand. However, this last alternative is not considered as reliable as the others because, during the heating cycle, the binder in the sand gives off gases which may accumulate in the empty cavity **17** and impair the bond which is to be created.

The bronze charge **14** is in the form of a cylindrical body which has an enlarged portion that fits within axial bore **15**, and a smaller portion that fits within a central recess formed in mold **13**. The charge, therefore, serves as a convenient means for centering blank **12** in the mold during make-up of assembly **11**. The charge may be a solid bronze casting, but preferably is a sintered mass of bronze powder because this form permits better control of composition. While various bronzes may be used, experience indicates that the composition should be free of zinc and nickel because these metals tend to separate from the other constituents and form a brittle interface which may crack under the service conditions encountered by the finished cylinder barrel. The composition should also have as low a lead content as possible because this metal will "bleed out" during heat treatment of the driving splines of the cylinder barrel. Bronzes having the following compositions, by weight, have proven acceptable:

a. 80 percent copper, 10 percent tin, 10 percent lead
b. 89 percent copper, 11 percent tin
c. 90 percent copper, 10 percent tin

However, the preferred charge **14** is made of a bronze containing 85 percent copper, 10 percent tin, and 5 lead, and which is purchased commercially in the nickel-free form.

It will be noted from FIG. **1** that the charge **14** is so positioned in assembly **11** that, when melted, the bronze will flow into mold cavity **17**. The volume of metal in the charge is greater than the volume of the cavity so that the liquid level of the molten mass will lie above the end face **16** of blank **12**. This measure insures that cavity **17** will be filled completely and that the molten bronze will be in contact with face **16** throughout its whole area.

After assembly **11** has been completed, it is placed in a furnace and supported therein in a level position, i.e., in a position which is sufficiently level to guarantee that the liquid level of the molten bronze will lie above face **16** throughout the full extent of the latter. The furnace should contain a non-oxidizing atmosphere, such as the filtered natural gas product commonly employed to control decarburization of the steel in blank **12** during heat treatment. In a typical process, the furnace is at a temperature of about 1,600°F when assembly is inserted, so the temperature must subsequently be raised to an elevated level above the melting range of the bronze and held there long enough to insure that all parts of assembly **11** reach a temperature which will produce a good metallurgical bond between the bronze and steel. Although bonding can be effected at an assembly temperature on the order of 1,900°F, experience indicates that a temperature of 1,950°F is needed in order to provide the degree of bonding reliability required for a production process. The furnace temperature and length of time this temperature must be maintained in order to achieve the required assembly temperature must be determined empirically because these factors vary with furnace design and loading, i.e., the number of assemblies **11** being processed at the same time. The final selection involves a compromise since higher temperatures shorten holding time but also cause excessive evaporation of bronze and, because of localized hot spots, involve some risk of melting portions of steel blank **12**. Our studies show that furnace temperatures above 2,000°F are too risky and are not really demanded by practical production considerations. For example, using a standard heat treating furnace capable of simultaneously processing thirty assemblies, we found that acceptable bonds were produced reliably at a furnace temperature of 1,990°F which was maintained for one hour.

During the heating cycle just mentioned, charge **14** melts and the bronze flows downward into mold cavity **17**. Since the volume of bronze in the charge is greater than the volume of the cavity, some of the molten metal will rise upward into bore **15** and around the outer periphery of blank **12**. In other words, the liquid level of the molten bronze mass will lie above the face **16** of blank **12**. This is of vital importance because it insures that there will be contact between the bronze and the steel over the entire area of face **16**. As a result, a sound metallurgical and mechanical bond will be effected over the entire interface.

At the end of the heating cycle, i.e., after all parts of assembly **11** have reached the selected bonding temperature, the furnace is allowed to cool so that the temperature of assembly reduces below the melting range of the bronze. Typically, this phase of the process consumes about 1 hour, furnace temperature decreases to about 1,400°F, and the temperature of assembly **11** drops to a level below 1,500°F. These conditions insure solidification of the bronze and permit opening of the furnace without risk of explosion of the controlled atmosphere. Assembly **11** is now removed from the furnace and allowed to air cool to room temperature. During these cooling phases of the process, some shrinkage may occur in the cast bronze valve plate blank. However, as mentioned above, the enlarged central mass of bronze and the insulation afforded by jacket **22** to tend to confine this effect to the annular region adjacent the inner periphery of face **16**, which is removed during final machining.

After assembly **11** has cooled sufficiently to be handled, blank **12** is removed from mold **13** and transformed into a completed cylinder barrel by the final finishing operations. These include:

1. Machining the inner and outer peripheral surfaces **24** and **25**, respectively, and the front face **26**.
2. Cutting and heat treating driving splines **27**.
3. Drilling, boring and honing cylinder bores **28** and end milling arcuate ports **29**.
4. Machining bonded valve plate **31** to form land **32**.
5. Grinding and lapping the faces of dynamic pads **19** and land **32**.

Although the foregoing description treats only the process steps of the present invention, it should be understood that, in the complete commercial process, bonding of the valve plate **31** is effected simultaneously with the cylinder liner bonding step of our application Ser. No. 93,130, or Ser. No. 93,298, both filed concurrently herewith.

We claim:

1. A process for producing a bonded bronze valve plate on the end of a steel cylinder barrel for a pump or motor comprising the steps of

a. fabricating a steel barrel blank (**12**) having an end provided with an annular face (**16**);
b. fabricating a mold (**13**) equipped with a surrounding heat sink (**22**) and formed to receive said end of the blank and define with said annular face a cavity (**17**) having a thickened cross section adjacent the inner periphery of said face (**16**);
c. preparing a mass (**14**) of bronze in the solid state which has a volume greater than the volume of said cavity (**17**);

d. uniting the blank (**12**), the mold (**13**) and the mass (**14**) of bronze to form an assembly (**11**) in which the mold is level, the blank is upright and is held in position to define said cavity by its own weight, and the bronze mass is so positioned that, upon being melted, it will flow into and fill the cavity;

e. heating said assembly (**11**) in a non-oxidizing atmosphere to a temperature between 1,900° and 2,000°F to thereby melt the bronze and cause it to fill said cavity (**17**) and form a metallurgical and mechanical bond with said annular face (**16**);

f. cooling said assembly (**11**) in the presence of the non-oxidizing atmosphere to solidify the bronze in said cavity;

g. further cooling the assembly (**11**) to room temperature; and

h. machining the final valve plate (**31**) from the bonded bronze member and, in the course thereof, removing an annular region of bronze adjacent the inner periphery of said annular face.

2. The process defined in claim **1** in which the mold is made of ceramic and is coated with a graphite release agent.

3. The process defined in claim **1** in which said assembly (**11**) is heated to a temperature of 1,950°F.

4. The process defined in claim **1** in which

a. the assembly (**11**) is cooled in the non-oxidizing atmosphere to a temperature between 1,400° and 1,500°F; and

b. said further cooling is effected in air.

5. The process defined in claim **1** in which

a. the barrel blank (**12**) is made of SAE 52100, 1045 or 4150 steel; and

b. the bronze mass (**14**) is a nickel-free composition containing, by weight, 85 percent copper, 10 percent tin, and 5 percent lead.

6. The process defined in claim **5** in which the bronze mass includes a sintered slug of bronze powder.

7. The process defined in claim **1** in which

a. the barrel blank (**12**) is formed with an axial bore (**15**) which is normal to and encircled by said annular face (**16**); and

b. the mass (**14**) of bronze is in the form of a cylinder which fits within said bore and has an integral portion which fits a central recess in the mold (**13**),

c. whereby the bronze cylinder serves to center the blank with respect to the mold in said assembly.

8. The process defined in claim **7** in which

a. the mold (**13**) is made of ceramic and is coated with a graphite release agent;

b. the barrel blank (**12**) is made of SAE 52100, 1045 or 4150 steel;

c. the bronze mass (**14**) is a nickel-free composition containing, by weight, 85 percent copper, 10 percent tin and 5 percent lead;

d. the assembly (**11**) is heated to a temperature of 1,950°F;

e. the assembly (**11**) is cooled in the non-oxidizing atmosphere to a temperature between 1,400° and 1,500°F; and

f. said further cooling is effected in air.

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