Jan. 23, 1934. R. D. PIKE 1,944,461

METHOD OF CENTRIFUGAL CASTING

Original Filed March 26, 1930 2 Sheets-Sheet 1

Fig. 1.

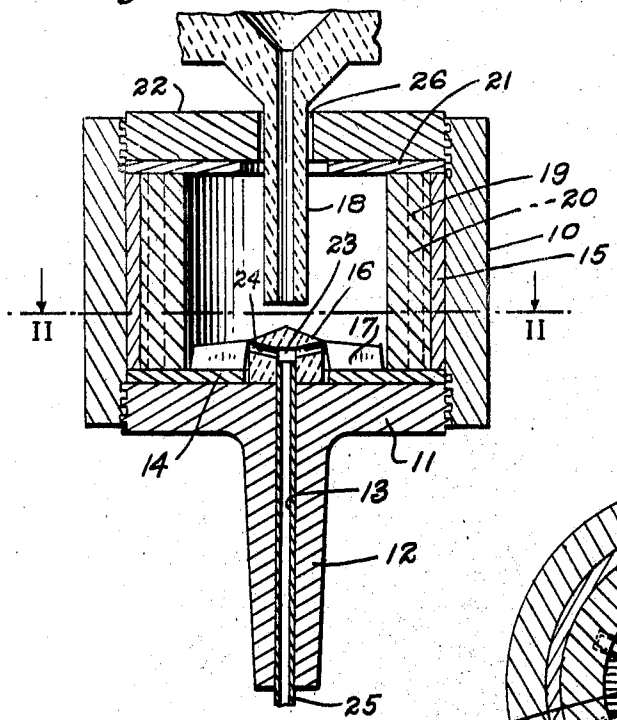



Fig. 2

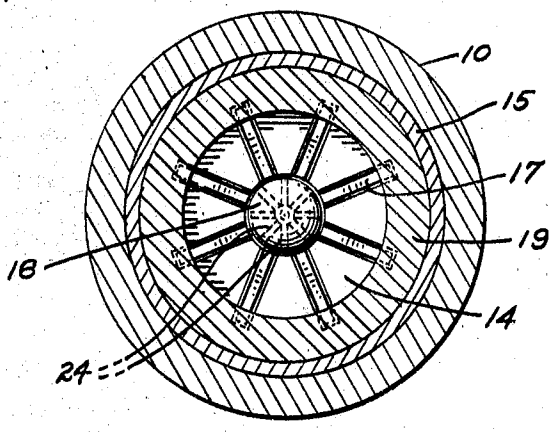
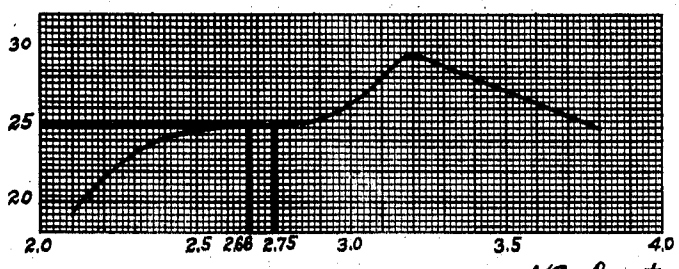



Fig. 3




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Fig. 5.

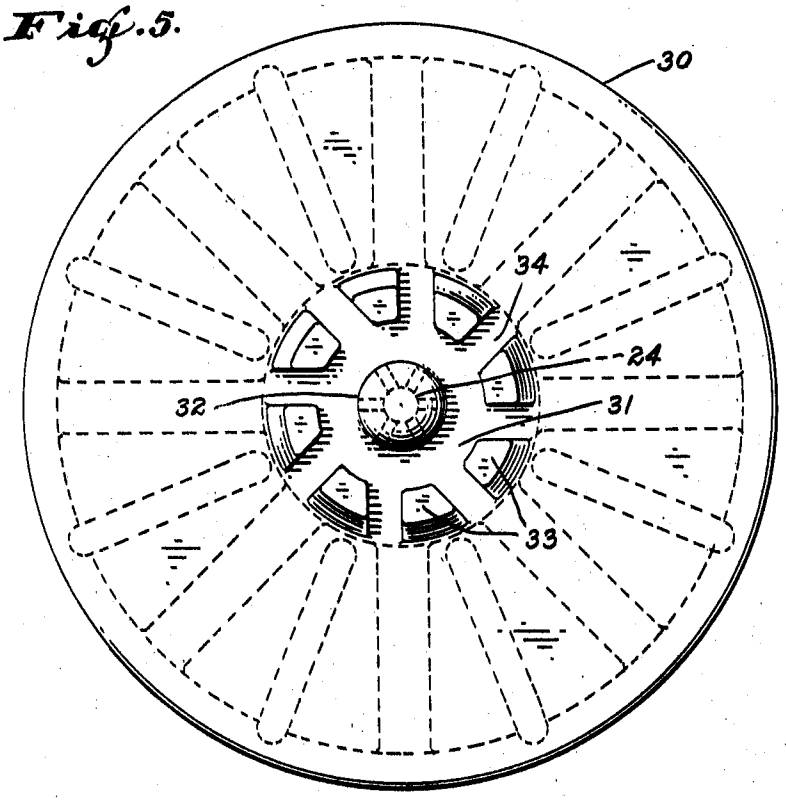
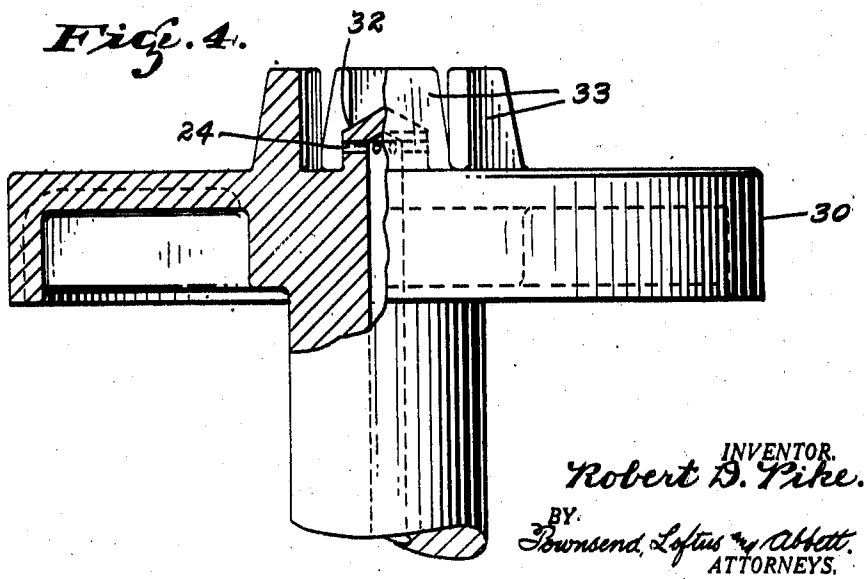



Fig. 4.




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# UNITED STATES PATENT OFFICE

1,944,461

## METHOD OF CENTRIFUGAL CASTING

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Original application March 26, 1930, Serial No. 439,059. Divided and this application January 19, 1932. Serial No. 587,464

6 Claims. (Cl. 22—204)

This case is a division of my application Serial No. 439,059, Centrifugal casting device, filed March 26, 1930, and it is also a continuation in part of my application Serial No. 408,263, Bearing bushing, filed November 19, 1929.

My invention relates to centrifugally casting and cast-welding compound or mixed metals which have a tendency to become non-homogeneous or of non-uniform composition under casting conditions, although the molten material at the beginning of the casting operation may be homogeneous or sufficiently so for all practical purposes.

I have discovered that separation of the components or non-uniformity of composition is caused by turbulence of the mixed metal and that there will be a tendency to preserve the original homogeneity of the metal to be cast, which tendency will be the greater the less the turbulence of the metal. My invention is accordingly applicable to the centrifugal casting of all molten metal mixtures which have a tendency to segregate when subjected to the usual method of centrifugal casting, irrespective of the components thereof or of the proportions present of such components, since such segregation is obviated by the use of my invention. I may mention as examples, and these are mentioned for purposes of illustration only, various steels and various bronzes consisting essentially of copper and lead. I shall describe my invention specifically with respect to the centrifugal casting or cast-welding of a bronze bearing metal consisting of about 27.5% lead, the balance being copper. These proportions of copper to lead may be varied to a great extent, for example, the content of lead may run up to about 40% or 45% or higher, or down to 20% or lower, it being understood further, as already stated, that the invention is applicable to other alloys, for example, as referred to in my application Serial No. 554,785, filed August 3, 1931, and that it is also applicable to totally different kinds of alloys, as already stated.

An object of my invention is to provide a method for centrifugally casting alloys or mixed metals so that the product will be free or reasonably free from segregation of the components.

A specific object of my invention is to provide a method for centrifugally casting copper-lead bronzes so that the product will be free from lead segregation.

Other objects of the invention are the avoidance of porosity and flaws due to flow lines.

Other objects of the invention will become apparent on reading the appended description.

With particular reference to the copper-lead alloy above referred to containing 27.5% of lead, the balance being copper, it has hitherto been impossible to make such castings by methods of centrifugal casting because of lead segregation and porosity in the walls of the casting and because of drainage of lead away from the inside face leaving, after machining the usual machine cut for finishing, considerably less than 20% lead on the inside face. Furthermore, it has been found to be impossible after many years of practice to cast pure alloys of copper-lead in sand, which are free from porosity and lead segregation. The cylinders made by my process make excellent bearing bushings for heavy duty high speed service and, as they possess properties not hitherto attainable in castings of similar composition, are a new article of great importance in the bearing field. In consequence of their very fine dissemination of the lead and entire freedom from occasional large masses of lead, they stand up under the most severe pounding at relatively high working temperatures without cracking, a characteristic also not hitherto attainable with copper-lead alloys.

When a molten alloy of copper-lead of the kind described cools to about 954° C. the copper begins to solidify and free molten lead begins to separate out, and herein mainly lies the difficulty hitherto encountered in the founding of this alloy. I have found that if the alloy be cast centrifugally in accordance with methods hitherto known, especially when the wall of the casting is over ¾ inch thick and the inside diameter over 3 inches, the turbulence of the metal which occurs as the molten alloy takes its position in the wall under the influence of centrifugal force permits the lead to gather together in large masses which results also in the production of porosity and in worthless castings. This phenomena is caused by the free molten lead which separates from the alloy during freezing while the latter is still pasty and therefore subject to turbulence under the intense centrifugal force acting upon it, the turbulence affording opportunity for the separate minute particles of molten lead to gather together into larger masses. I have discovered that if the alloy be flowed into its place in the wall of the casting substantially without turbulence, the lead remains in situ and a fine grained perfect casting results.

One of the principal features of my invention is the means and methods which I employ to flow the metal into the wall of the casting substantially without turbulence. Another feature of my

invention is the method employed to counteract the tendency of the lead to flow outwardly radially under the influence of centrifugal force during the time interval while the casting is still plastic. I have also discovered that for each diameter of casting there is an optimum revolving speed which may be described as the result of a compromise between the need for rapidly putting the metal into the wall and the need for minimizing drainage of lead outwardly. I have also found that the optimum temperature of the centrifugal mold is from 250° to 400° C. but I may heat the mold only to 150° C. which I have found is still sufficient to give good results; the temperatures varying according to the size and wall thickness of the casting and the weight of the mold itself. These mold temperatures permit the metal to fill out the mold fully and at the same time give a rapid chill to the casting which helps prevent segregation of lead. However, all conditions being correct, I have found that it is not possible to prevent a certain amount of lead drainage and that if I start with a molten alloy containing 27.5% lead, balance copper, the lead content of the inside face of the casting will range from 15% to 20%, which is lower than desirable for a bearing. I have found that I can overcome this difficulty by pouring a considerable excess of the alloy and allowing the excess metal in the mold to accumulate on the inside walls of the cylinder. By properly choosing the excess metal in each I have found that when the bushing is machined out to the finished inside diameter, the inside surface will have from 23% to 26% lead and the outside surface, after the normal machining out, will have from 25% to 28% lead. I remelt the excess borings from the inside and cast with a subsequent lot of metal.

I have shown various ways of avoiding turbulence in my prior applications filed Nov. 22, 1929, Serial No. 409,046, filed December 10, 1929, Serial No. 413,090, and filed April 8, 1930, Serial No. 442,574, as well as in my prior applications previously referred to above. As an illustration of one manner of avoiding or decreasing turbulence in the centrifugally cast metal, I refer to the accompanying drawings, whereon—

Fig. 1 is a vertical, sectional view of a rotor set-up showing a casting in place,

Fig. 2 is a plan view in section taken along line II—II of Fig. 1.

Fig. 3 is a schematic diagram showing the radial disposition of the lead in the alloy when cast in accordance with my invention,

Fig. 4 is a side elevation partly in cross section of a modification of the bottom plate and vanes, and

Fig. 5 is a plan view thereof.

For the purpose of illustrating my invention, I shall describe a method for making a bearing bushing which, when finished, will have an outside diameter of 3.5 inches, an inside diameter of 2.75 inches, and a length of 3½ inches, and which, when finished, will have on its inside surface a content of 24% to 26% of lead.

In carrying out my invention I have found it preferable to employ a spinning means such as is illustrated in my prior application Serial No. 345,707, filed March 9, 1929. With this apparatus I propose to also fill the casting chamber with a hydrogen and sulphur free producer gas, as therein disclosed, before proceeding with the casting.

For the purpose of centrifugally casting a bushing of the above character, I provide a rotor set-up, as illustrated in Fig. 1, in which 10 is a steel shell provided with an inside threaded portion at the top and bottom. The bottom closure of the rotor is effected by a threaded cap 11 having a tapered shank 12 through which there is a central longitudinal bore 13. An annular plate 14, preferably made of so-called high temperature alloy of iron, nickel and chromium, rests on top of the cap 11 when the latter has been screwed into place, and a sleeve 15, preferably made of cast iron, rests on the plate 14. The plate 14 is illustrated as having a graphite distributor 16, to be described hereinafter, inserted through its center, but this distributor 16 can, if desired, be made integral with the plate 14 and the entire plate and distributor can, if desired, be fashioned out of one piece of graphite or suitable metal such as that above referred to. Formed integral with the top of the plate 14, I provide radial vanes 17, of which eight are usually employed. These vanes 17 are preferably made a little higher at their inner than at their outer extremities, and a suitable height is approximately ⅜ inch at the inside end and ¼ inch at the outside end. It is to be understood that these dimensions may be varied over a considerable range at the option of the designer. The outside extremities of the vanes 17 are preferably made to terminate just short of the finished diameter of the casting. A pouring pipe 18, preferably made of the same material as the plate 14, is provided to deliver the molten alloy at a point directly above the center of the distributor 16; and 19 designates a casting in place. The dotted lines 20 in this casting outline the portion of the casting which will be retained after finishing. In other words, the material inside of the inner dotted line and that outside of the outer dotted line is surplus material.

On top of the cylinder 15 there is provided a cast iron washer 21 and the top closure is made by screwing a steel cap 22 into place within the shell 10. The distributor 16, made of graphite or heat resistant steel, is placed in the central hole in washer 14 and preferably held in place by a key (not shown). This distributor 16 is provided with a central conduit 23 and branch conduits 24. It will be apparent from this that a stream of gas flowing up from a pipe 25 will enter the conduit 23 and pass into the rotor assembly through the conduits 24 and then upwardly and out through an opening or clearance 26 in the top of the closure member 22.

An alternative type of bottom plate is illustrated at 30. In this type there is provided a central well 31, into which the metal first drops. In the center of this well is the projection 32 which diverts the metal away from the center and away from the gas holes 24.

Surrounding the well 31 are a number of projections 33, usually eight, which form between them the passages 34. These passages may be disposed radially, or semi-radially, or may be curved like the passages in a centrifugal pump. Their length radially is determined by the inside diameter of the bushing.

The criteria of the design of the bottom plates and vanes, however, worked out in detail, is to uniformly and rapidly project the metal onto the wall of the bushing by centrifugal force and with a minimum of turbulence.

In the example cited, wherein I make a casting to finish at 3.5 inches outside diameter and 2.75 inches inside diameter by 3½ inches long,

the inside diameter of the sleeve 15 is made 3.75 inches and its length 3.75 inches. Before the molten alloy is poured, the rotor assembly is preferably heated to 250° to 350° C. in a separate electric resistance furnace arranged for this purpose and the speed of rotation of the assembly is brought to approximately 2050 R. P. M. As indicated above the range of mold temperature is such that the temperature is insufficient to allow the lead content to be materially reduced by centrifugal force but sufficient to prevent premature freezing of the outside surface of the casting before the mold has been completely filled. This will give a centrifugal effect of $2050\times2050\times1.875$=about 7,880,000. Incidentally, this number has no absolute numerical significance, but is proportional to the centrifugal force in pounds. This centrifugal effect is proportional to the centrifugal force in pounds, the formula being

$$E=(\text{R. P. M.})^2\times\frac{D}{2},$$

wherein "E" is the centrifugal effect, "D" is the diameter of the revolving cylinder, and "R. P. M." is the number of revolutions per minute. The conventional formula is $F=Ma$, wherein "F" represents force, "M" represents mass, and "$a$" represents acceleration. In the art of centrifugal casting there is no unchangeable mass, and hence it is found convenient to employ a formula such as

$$E=(\text{R. P. M.})^2\times\frac{D}{2}$$

for determining the centrifugal effect which is proportional to the centrifugal force in pounds but independent of mass. The temperature of the copper-lead alloy is then brought to from 1204° to 1250° C., the alloy being melted preferably in a high frequency induction furnace.

In making such a casting, I pour sufficient of the copper-lead alloy to give a bearing bushing having an inside diameter of about 2 inches. By proceeding in this manner and by starting with an alloy consisting of copper and lead and containing 27.5% lead in the molten condition, I get radial distribution of lead in the rough casting as shown typically in Fig. 3, whereon the distances from the inner face of the casting towards the outside face thereof are represented as abscissæ and the percentages of lead at such distances are represented as ordinates. It will now be seen that if I bore this casting out to the finished bore of 2.75 inches, the inside face will contain 24.5% lead, which is a desirable content from the standpoint of excellent anti-friction properties. Furthermore, the lead content line assumes a typical wave form and the maximum lead content is toward, but not at the outside. I now take the turnings from the outside and the borings from the inside, pass over a magnetic separator, briquette in a suitable press and remelt and cast into ingots. The latter are analyzed and remelted with additions of lead or copper to give substantially 27.5%, and recast with a fresh lot of the alloy. The average amount of lead in the casting can be somewhat increased by using a liquid casting alloy containing more lead but I have found that a suitable content of the liquid alloy used for pouring is 27.5% to 30% lead. The mechanism of lead segregation is well illustrated by the curve of Fig. 3. This shows that the flow of lead outwardly has been arrested by the freezing of the alloy and by the packing together of the copper grains under the action of centrifugal force.

In making a casting of the above character, I proceed as follows: The rotor set-up is brought, as previously suggested, to a temperature of 250°–350° C. and then placed in the spinner. The latter is immediately started and the rotor timed at 2050 R. P. M. The hydrogen and sulphur free gas is then introduced through the pipe 25 so as to fill the rotor set-up. In the meantime a measured amount of copper-lead alloy is drawn into a suitable crucible and is quickly poured through the pipe 18 into the revolving rotor set-up and the latter is then kept rotating for about 30 seconds, when it is stopped, and the rotor set-up removed from the spinning apparatus. Under these conditions the molten alloy pouring downwardly out of the pipe 18 impinges upon the distributor 16 and flows in between the vanes 17. These latter vanes are analogous to the vanes of a centrifugal pump and immediately impart to the molten metal the full rotational speed of the rotor set-up. The centrifugal force engendered thereby forces the metal outwardly in a radial direction at high speed and when the molten metal strikes the inner wall of the cylinder 15, it overflows it in a strictly longitudinal direction at high speed. The principal point to be here emphasized is that the molten metal when it strikes the inner face of cylinder 15 has a rotational velocity almost as high as cylinder 15 and that, therefore, there is but little relative rotational motion between the cylinder 15 and the metal. This results in a speedy, almost instantaneous distribution of the molten metal in a perfect hollow cylinder inside of the cylinder 15 with practically no turbulence. On the other hand, if an attempt be made to cast with a smooth bottom plate, particularly when large masses of metal weighing over 15 pounds are cast, the molten metal will churn around with great turbulence over the bottom plate and as it takes its place in the wall this churning will continue until the friction between the metal and the inside face of the cylinder 15 gradually imparts the full rotational speed to the metal. Furthermore, the churning of the metal greatly lengthens the interval between the striking of the metal on the distributor 16 and its final placing in the casting. The result of these phenomena is that a large casting made without the vanes 17 or 33 is worthless because of lead segregation and porosity whereas the same casting made with the vanes is perfect. The same type of imperfect casting results from pouring the alloy into a horizontally disposed centrifugal casting machine of any well known type and for the same reason. The bottom plate 14, with its vanes 17 or 33, acts virtually as a centrifugal pump which distributes the metal at extremely high velocity and with minimum turbulence into its place in the wall.

After the rotor has been removed from the spinner, about 20 minutes is required for a cooling of the casting. Then the rotor assembly can be disassembled and the casting removed.

By an alloy of copper-lead, I refer principally to the one described above, but it will be obvious that the same principles of my invention will apply to alloys of copper and lead containing other metals in which a phenomena of lead segregation similar to that described occurs, and to other alloys in which similar difficulties are encountered due to separation of a low fusing point constituent at the freezing point of the alloy; or to any metal which, because of its property of

rapid freezing or other characteristic, has its quality improved by the use of the described mold. It will also be obvious to those skilled in the art that this mold may be applied to other metals than alloys of copper and lead such, for example, as steel and that a wide latitude in choice exists in selecting the material for the mold and the bottom distributing plate to meet the special requirements of any given metal. It will also be plain that the temperature of the mold may be varied widely to meet the requirements of the metal being cast. For example, steel, because of its high freezing point not only requires the bottom vanes for rapid distribution to prevent turbulence and unsound spots in the casting, but the general temperature level of the mold may advantageously be above a bright red heat, and in casting steel cylinders in this type of mold the liner of the latter may be of some ceramic material as well as the distributing bottom and the temperature of the inside of the mold may be raised to any suitable level by playing a torch inside the mold prior to casting the metal.

While I have, for the sake of clearness and in order to disclose my invention so that the same can be readily understood, described and illustrated specific devices and arrangements, I desire to have it understood that this invention is not limited to the specified means disclosed but may be embodied in other ways that will suggest themselves, in view of this broad disclosure, to persons skilled in the art. It is believed that this invention is broadly new and it is desired to claim it as such so that all such changes as come within the scope of the appended claims are to be considered as part of this invention.

The "optimum" temperatures mentioned herein are to be preferred but are not intended as delimiting the range that may be employed in practice under differing conditions.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. The method of centrifugally casting bushings of a copper-lead alloy which consists in heating a centrifugal mold assembly from 150° to 300° C. and rotating the latter so as to impart a centrifugal effect of from 4,000,000 to 10,000,000, and pouring into said mold while rotating a molten alloy of copper-lead containing not less than 25% lead at a temperature of from 1204° to 1250° C.

2. The method of centrifugally casting bushings of a copper-lead alloy which consists in heating a centrifugal mold assembly from 150° to 300° C. and rotating the latter so as to impart a centrifugal effect of from 4,000,000 to 10,000,000, pouring into said mold while rotating a molten alloy of copper-lead containing not less than 25% lead at a temperature of from 1204° to 1250° C., and overpouring the said alloy so that when the casting is bored out to its finished diameter, the lead content of the finished surface will be not less than 23%.

3. The method of centrifugally casting bearing bushings, which comprises pouring an alloy consisting essentially of 27.5% lead and 72.5% copper at a temperature of substantially 1200° to 1250° C. centrally into a mold at a temperature of 250° to 350° C., rotating on a vertical axis at a speed of about 2050 R. P. M., immediately moving said molten alloy radially away from said axis and at an angular velocity substantially equal to that of said mold, and maintaining rotation until the cast metal has set.

4. The method of centrifugally casting bearing bushings, which comprises pouring an alloy consisting essentially of 27.5% lead and 72.5% copper at a temperature of substantially 1200° to 1250° C. centrally into a mold filled with carbon monoxide at a temperature of 250° to 350° C., rotating on a vertical axis at a speed of about 2050 R. P. M., immediately moving said molten alloy radially away from said axis and at an angular velocity substantially equal to that of said mold, and maintaining rotation until the cast metal has set.

5. The method of centrifugally casting bearing bushings, which comprises pouring an alloy consisting essentially of 27.5% lead and 72.5% copper at a temperature of substantially 1200° to 1250° C. centrally into a mold filled with a gas free from sulphur and free hydrogen and oxygen at a temperature of 250° to 350° C., rotating on a vertical axis at a speed of about 2050 R. P. M., immediately moving said molten alloy radially away from said axis and at an angular velocity substantially equal to that of said mold, and maintaining rotation until the cast metal has set.

6. The method of centrifugally casting bushings of a bearing alloy containing copper and lead, the lead content being not less than 20%, which consists in heating a centrifugal mold assembly to a temperature of 150° to 400° C., rotating the latter so as to impart a centrifugal effect of from 4,000,000 to 10,000,000, and pouring into said mold while rotating the same said alloy at a temperature of from 1204° to 1250° C.

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