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CASTING METHOD

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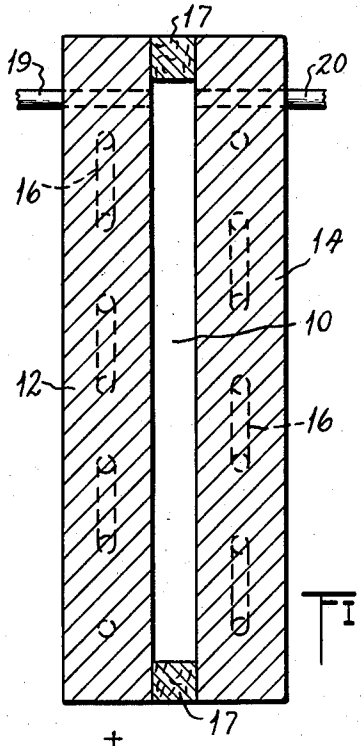


Fig. 1

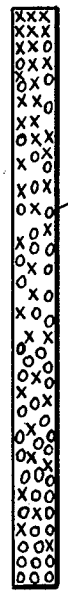


Fig. 2

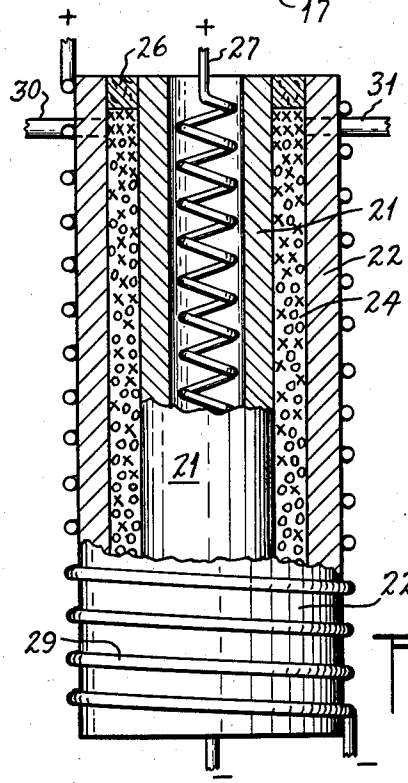


Fig. 4

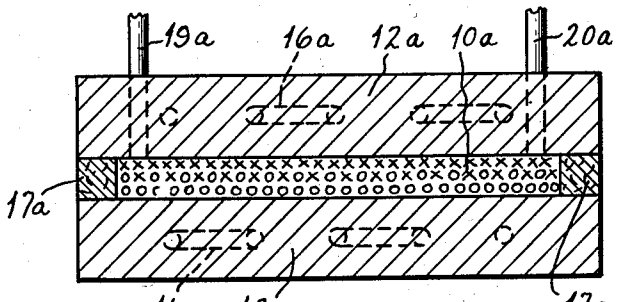


Fig. 3

INVENTOR.
WARREN JACKSON, JR.

BY

Campbell, Brumbaugh, Free & Graves
ATTORNEYS

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CASTING METHOD

Warren Jackson, Jr., Lyndhurst, Ohio, assignor to The Standard Oil Company, Cleveland, Ohio, a corporation of Ohio

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The present invention relates to a novel method of casting solid material consisting of at least two components and to the castings so produced.

To the best of my knowledge the art relating to the casting of solids containing two or more components, e. g., metal alloys and mixtures of hydrocarbons that are solid at ordinary temperatures, has been concerned primarily with the problems of obtaining castings that are uniform in composition throughout the mass of the article being cast and to the discovery of novel combinations of components that will yield castings of certain properties or combination of properties such as strength, ductility, thermal and electrical conductivity, expansion, and the like.

I have approached the problem of making castings from an entirely different point of view, namely, from the point of view of obtaining castings containing two or more components in which the relative proportion of one (or more) of the components is a maximum at one surface of the casting and becomes progressively lower toward the opposite surface and the relative proportion of one (or more) of the other components is at a maximum at said opposite surface and becomes progressively lower toward the surface having the maximum concentration of the first components.

The term "surface" is used generically herein to apply to any of the exterior surfaces of a casting. Thus, for example, the term "surface" may apply to the flat side of a thin strip or to a relatively small surface at one extremity of such a strip.

It will readily be appreciated that a casting in the form of a thin strip of solid material consisting of two or more components in which the concentration of one (or more) of the components is at a maximum at one extremity of the strip and the concentration of one or more other of the components is at a maximum at the other end of the strip and the concentrations of said components decrease progressively toward and beyond the center of the strip will have great utility for a variety of purposes, e. g., the determination of the best proportion of the ingredients for a particular purpose. Thus, for example, a casting, in the form of a thin strip, of magnesium and aluminum in which the concentration of magnesium is at or near 100% at one end, the concentration of aluminum is at or near 100% at the other end and the respective relative proportions decrease progressively toward and beyond the center will be a valuable research tool since it is possible to test the properties of any desired portion of the strip and thus arrive at the optimum relative proportions for a particular purpose without necessity of making an excessively large number of individual and homogeneous castings in which the proportions vary from 100:0 to 0:100.

The method of the invention is also of utility in casting objects having other properties in gradually increasing degree such as, for example, optical density, electrical resistance, and the like. Thus, for example, if a dye and a wax are two components cast by the method of the invention, a wax casting will be obtained having a maximum concentration of dye at one surface and a minimum concentration of dye at the other. Similarly, materials of different electrical resistance characteristics may be cast in such a manner that the casting will have excellent electrical conductivity at one surface and high electrical resistance at the opposite surface.

It will also be appreciated that a casting, in the form of a thin strip, wherein the relative proportion of one of the components is at a maximum on one side, the relative proportion of the other component is at a maximum on the other side and the relative proportions of the components decrease progressively toward and beyond the center will also have great utility. Thus, for example, if such strips are composed of metal components they will have superior thermal conductivity while presenting one type of metal at one face and a different metal at another face. Such strips would have particular utility as bi-metallic thermostat elements and would be of advantage in such use by reason of the fact that the shearing stress, which in bi-metallic elements made of two metal strips of different materials joined together is inherently concentrated at the plane of junction, is distributed throughout the element and would hence possess superior sensitivity and accuracy.

In accordance with my invention, material containing at least two components, mixtures of which are solid in the temperature range within which they are to be used or tested and in which the relative proportion of one (or more) of the components is at a maximum at one surface and becomes progressively lower toward the opposite surface, and the relative proportion of one (or more) of the other components is at a maximum at said opposite surface and becomes progressively lower toward said one surface, is cast by confining the components, in a liquid state, in a chamber defined by closely and substantially equidistantly spaced walls of heat conductive, inert material, maintaining one of the walls at a relatively high temperature below the boiling point of the lowest boiling component and maintaining the other of said walls at a relatively low temperature above the melting or freezing point of the component having the highest melting or freezing point until the relative proportions of the components vary in different portions of the chamber or reach a state of equilibrium in a given portion of the chamber. When the desired variation in relative proportions, or a state of equilibrium has been reached, both walls are cooled to a temperature below the eutectic temperature of the components to solidify the liquid.

The method of the present invention is applicable to the casting of liquifiable or normally liquid components one or more of which may be metal, e. g., mercury, gallium, Woods metal, magnesium, aluminum, copper, lead, iron, and the like, or thermoplastic material, e. g., waxes, resins, and the like, provided that all proportions of the components in the casting are solid in the temperature range within which the casting is to be used or tested.

The term "eutectic" temperature, as used herein applies not only to the lowest constant melting point of any mixture of the constituents of a metal alloy, but also to the lowest constant melting point of any mixture of other components, e. g., organic components, of the mixture being cast.

While the invention is not to be limited by any theory expressed herein, it is believed that the novel results obtained by the method of the present invention are due to thermal diffusive forces applied to the molecules of the components in the liquid or liquified mixture in that different quanta of energy of translation are imparted to different molecules in a liquid mixture when a mixture is

subjected to a temperature gradient. It has been observed that the degree to which different molecules tend to accumulate at the lower and higher ends, respectively, of the temperature gradient depends upon the magnitude of the temperature gradient which is defined as the difference in temperature per unit of distance. Inasmuch as the difference between the higher and lower temperatures to which a mixture of components to be subjected is limited by the boiling point of the lowest boiling component and the melting or freezing point of the highest melting component, it is desirable, in order to achieve a high temperature gradient, to make the distance across which the temperature gradient is effecttive, i. e., from one wall of the chamber to the other, as small as possible. Thus, while the distance between the walls and consequently the thickness of the casting is not particularly critical, it is preferred that the wall spacing in the chamber in which the casting is effected be of the order of a fraction of an inch, preferably as small as about 0.01 to about 0.15 inch.

It has also been observed, that thermal diffusion forces act surprisingly rapidly in bringing about an accumulation of certain molecules or atoms adjacent one wall and of other molecules or atoms adjacent the opposite wall. For this reason, where maximum differences in concentration of the components at opposite surfaces of the casting are not desired, it is within the scope of the invention to solidify the liquid mixture within the chamber shortly after a temperature gradient has been effectively imposed upon it.

When it is desired to cast a flat strip, the chamber in which the casting is effected may be operated in a vertical or horizontal position depending upon whether a gradation of the relative proportions of the components is desired from side to side or from end to end. If the chamber is operated in the vertical position, the molecules accumulating adjacent the relatively hotter wall will ascend by thermal convection toward the upper end of chamber and the molecules accumulating adjacent the relatively cooler wall will descend, likewise by thermal convection, to the lower portion of the chamber. Thus, after equilibrium conditions have been obtained and both walls have subsequently been cooled, preferably with rapidity, to solidify the material in the chamber, a casting will be produced which, at one end, consists exclusively or contains a maximum concentration of one of the components and at the other end consists exclusively or contains a maximum concentration of another component. When the thermal diffusion separation chamber is operated vertically, as described, it may be formed by two closely spaced flat plates, by the inner surface of an outer tube and the outer surface of an inner concentric tube or by any other desired configuration of substantially equidistantly spaced walls.

If it is desired to cast a strip wherein the relative proportions of the components vary from side to side, the chamber is operated in the horizontal position, the wall that is heated to the relatively higher temperatures preferably being on top. In this embodiment of the method, thermal circulation of the components within the chamber is substantially absent, the molecules of one of the components again accumulating adjacent the relatively highly heated wall and the molecules of another component accumulating adjacent the less highly heated wall. When a state of equilibrium has been obtained the walls are, as in the vertical embodiment of the method, cooled, preferably with rapidity, to solidify the mixture.

The advantages and utility of the method and product of the present invention will become further apparent from the following description made with reference to the accompanying drawing wherein:

Figure 1 is a cross-sectional view in elevation of a chamber in accordance with one embodiment of the invention;

Figure 2 is a schematic view of a casting formed in the manner illustrated in Figure 1;

Figure 3 is a cross-sectional view in elevation of apparatus similar to that shown in Figure 1 wherein the chamber used is in a horizontal position; and

Figure 4 illustrates schematically an embodiment in which castings in shapes other than flat strips, e. g., tubes or cylinders, may be formed.

Referring now to Figure 1, the chamber **10** for forming a casting such as that shown at **11** in Figure 2, is defined by closely and substantially equidistantly spaced walls **12** and **14** provided with means, such as coils **16** embedded therein, for maintaining the walls at different preselected temperatures. The ends of the chamber **10** are sealed by any suitable means such as a gasket **17** and preferably two conduits **19** and **20** communicating with the exterior of the apparatus are provided, one for introducing the mixture of components to be passed into the chamber **10** and the other for venting the chamber.

In accordance with one preferred embodiment of the method of the invention, two or more components in liquid or liquified form, e. g., 50 parts lead and 50 parts tin, are introduced into the chamber **10** by way of conduit **19** at temperatures above their melting points of 327.4° C. and 232° C., respectively. One of the walls **12** and **14** is maintained at a temperature above about 327° C., the melting point of the component having the highest melting point. The other of the walls is maintained at a higher temperature but below 1620° C., the boiling point of the lowest boiling component. After the relative proportions of the components in a given portion of the chamber **10** have reached a state of equilibrium, the walls **12** and **14** are rapidly cooled to a temperature below the eutectic point, e. g., below about 185° C., and preferably to room temperature, to solidify the liquid.

The casting thus obtained, shown schematically in Figure 2, will consist predominantly of tin, indicated by *x*'s in Figure 2, at one end and of lead, indicated by small circles at the other end, the relative proportions of lead and tin decreasing towards and beyond the mid-point of the strip, as indicated in Figure 2.

The embodiment illustrated in Figure 3 is substantially similar to that shown in Figure 1 except that the chamber **10***a* is horizontal, the walls **12***a* and **14***a* are likewise horizontal, and the conduits **19***a* and **20***a* communicate with the opposite ends of the chamber. A strip cast in a chamber of this type has a gradation of concentration from side to side, as indicated by the small *x*'s and circles shown in the chamber **10***a*. Strips so made of two metals would be of great utility as bimetallic thermostat elements.

The embodiment illustrated in Figure 4 comprises two concentric tubes **21** and **22** forming an annular chamber **24**. The tubes are maintained out of contact with another by means of ring shaped gaskets such as gasket **26**. The temperature of the inner tube **21** is controlled by any suitable means such as a coil of resistance wire **27** and the temperature of the outer tube **22** may likewise be controlled by any suitable means such as a coil of resistance wire **29**. Conduits **30** and **31** communicating with the chamber **24** are provided for introducing the components to be cast and venting the chamber.

In operation, the procedure is substantially the same as described in reference to Figure 1, it being preferable that the inner and outer tubes **21** and **22** be constructed of a material having respectively higher and lower thermal expansion coefficients than the thermal expansion coefficients of the components being cast so that the cast tube may be removed from the chamber with a minimum of damage to the tubes **21** and **22**.

It is to be expected that various modifications will readily occur to those skilled in the art upon reading this description. All such modifications are intended to be included within the scope of the invention as defined in the accompanying claims.

I claim:

1. A method of casting solid material containing at least two components that are non-reactive and miscible with one another in the liquid state which comprises confining the components, in a liquid state, in a chamber defined by closely and substantially equidistantly spaced walls of heat conductive, inert material, maintaining one of the walls at a higher temperature below the boiling point of the lowest boiling component and maintaining the other of said walls at a lower temperature above the solidification temperature of the highest melting component until there is a variation in the concentrations of the components in different portions of the chamber, and then quickly cooling both walls to a temperature below the eutectic temperature to solidify the liquid.

2. The method defined in claim 1 in which the chamber is in a vertical position.

3. The method defined in claim 1 wherein the chamber is in a horizontal position.

4. The method defined in claim 1 wherein the walls defining the chamber are flat.

5. The method defined in claim 1 wherein the chamber has an annular shape defined by the walls of vertical concentric tubes.

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