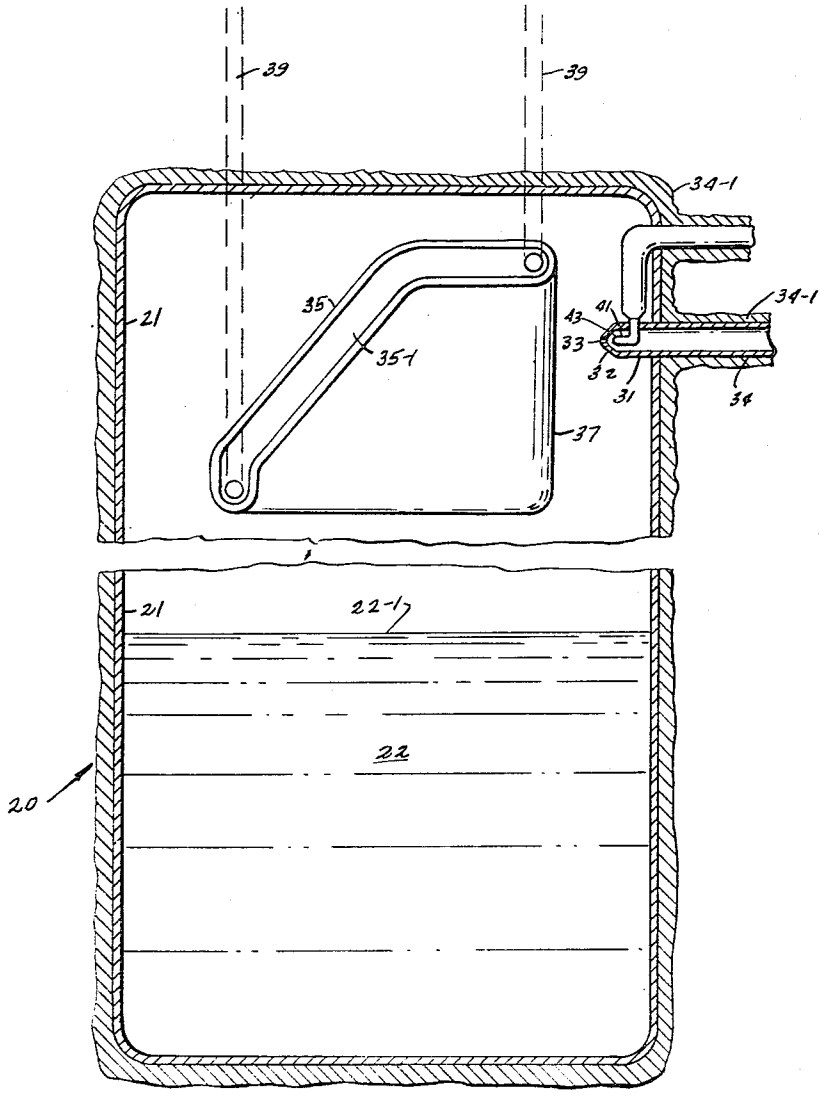
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PREPARATION OF IMPERMANENT PATTERNS OF COMPACTED FROZEN MERCURY POWDER PARTICLES

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PREPARATION OF IMPERMANENT PATTERNS OF COMPACTED FROZEN MERCURY POWDER PARTICLES

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This invention relates to impermanent or disposable patterns which are used in forming shell molds for precision casting, to the preparation of such patterns and to the preparation of shell molds made with such patterns.

Impermanent patterns formed of frozen mercury, as disclosed in Kohl Patent 2,400,831, have been found of great value in the precision casting art because they make it possible to produce thin-walled porous shell molds with cavities of fine surface finish, which in turn, make it possible to produce out of cast metals having a high melting point intricate shaped articles such as hollow turbine buckets, or the like with a fine surface finish, and also other high precision cast articles such as wave guides which are cast out of aluminum.

Heretofore, frozen mercury patterns have been produced by pouring liquid mercury into a partible master mold, the pattern cavity of which was lubricated with a lubricant such as acetone. The liquid mercury was then frozen in the mold cavity whereupon the mold was opened and the frozen mercury pattern removed therefrom for use in forming with it the desired shell mold.

A major cost item in the manufacture of precision cast articles by shell molds formed with frozen mercury patterns is the cost of making the frozen mercury pattern out of liquid mercury poured into a partible master mold. Among the factors responsible for the high cost of manufacturing frozen mercury patterns is the fact that when forming complex thin walled frozen mercury patterns, the liquid mercury must be frozen slowly in a rather laborious way to avoid shrinkage. In addition, the liquid mercury must be frozen in expensive dies made of a material such as hardened tool steel or stainless steel to avoid contamination of the mercury, as most other metals amalgamate with the liquid mercury.

Among the objects of the invention is a process for producing a frozen mercury pattern for precision casting which eliminates the laborious and relatively slow process of forming such patterns involving pouring of pure liquid mercury into a partible master mold and then slowly freezing it therein, and a novel frozen mercury pattern produced by such improved process of the invention.

The foregoing and other objects of the invention will be best understood from the following description of exemplifications of the same, reference being had to the accompanying drawings wherein the drawing is a diagrammatic side view of an apparatus illustrating one method of preparing powdered mercury particles for use in the process of the invention.

Impermanent patterns formed of frozen mercury in the manner disclosed in the Kohl Patent 2,400,831 have been found of great value in precision casting of complicated shaped objects, such as turbine buckets and wave guides because the very small dimensional change of frozen mercury near its melting or freezing temperatures makes it possible to form on frozen mercury patterns thin walled molds that would crack if formed around a

pattern of wax or like material which expands to a substantial extent when it is heated to a melting or decomposition temperature. Such frozen mercury patterns are also of great value in precision casting because they make it possible to form therewith thin walled shell molds with much finer refractory particle material, such as zirconium silicate, stabilized and unstabilized zirconium oxide, beryllium oxide and the like, resulting in mold cavities of very fine surface finish yielding castings of a correspondingly fine surface finish, and which have also the property of exhibiting high thermal shock resistance and of not cracking when casting into them metals of high melting point, such as stainless steel alloys. Another outstanding advantage of such thin shell molds obtainable with frozen mercury patterns is the fact that they may be produced to exhibit high porosity which is of great advantage in providing for the escape of gases developed when molten metal of high melting point is poured into the mold cavity.

However, as explained above, the cost of making patterns of pure frozen mercury for use in making precision cast metal parts was heretofore a major item in the cost of making therewith precision cast metal articles.

The present invention is based on the discovery that the production of frozen mercury patterns for precision casting molds of the type described above may be greatly simplified and much more economical and the process for producing the desired frozen mercury patterns greatly simplified by providing the required mercury in the form of frozen mercury powder particles which are used for compacting them into the properly shaped frozen mercury patterns by procedures similar to the hot pressing processes used for forming out of refractory metal powder particles shaped articles of desired characteristics.

According to the invention, frozen mercury powder particles are compacted into a solid pattern body of the desired shape by conventional compacting dies while the frozen mercury particles are maintained at a temperature in the range between about 20 to 40° C. below the freezing temperature of the mercury. A compacting pressure of .5 to 3.5 t. s. i. (tons per square inch) is sufficient for uniting or bonding a body of such frozen mercury particles into a solid frozen mercury pattern of the required strength and finish which may be used for forming therewith thin-walled porous shell molds of the same desired characteristics as obtainable prior to the invention only with frozen mercury patterns produced by freezing liquid mercury in the properly shaped partible master mold of stainless steel material.

Since the frozen mercury powder particles are not in a liquid state while they are compacted into the solid pattern, the compacting die may be made of metals which would amalgamate with liquid mercury, most such metals being immune to frozen mercury, and having the property of not amalgamating or reacting with frozen mercury.

As a result, the compacting dies required for forming out of the frozen mercury powder particles, the desired solid pattern may be made of any of the known readily machinable relatively soft metals and metal alloys at a fraction of the cost required for producing out of hard stainless steel partible master molds heretofore required for slowly freezing therein the liquid mercury into the required frozen mercury patterns.

In accordance with the invention, the required frozen mercury powder particles are produced by atomizing liquid mercury which has been cooled to a temperature somewhat higher than the freezing temperature of mercury, for instance, 1 to 4° above the freezing temperature of mercury which is about —40° C. at atmospheric pressures. So precooled liquid mercury may be atomized into fine frozen mercury as by discharging it through a nozzle with a stream of compressed fluid cooled down or

supercooled to a temperature materially below the freezing temperature of the mercury, and discharging the so atomized frozen mercury powder particles into a vessel wherein it is subjected to and maintained at a temperature considerably below the freezing temperature of the mercury powder particles under conditions which prevent their agglomerating or merging into a continuous mass of frozen mercury.

Inert gases such as carbon dioxide, nitrogen or helium, may be in such supercooled condition for atomizing such precooled liquid mercury which is near its freezing point into powdered frozen mercury powder particles.

In accordance with the invention, the atomized frozen mercury powder particles are discharged into a liquid maintained at a temperature considerably below the freezing temperature of mercury as a part of the process in which precooled liquid mercury which is on the verge of freezing is atomized into frozen mercury powder particles.

In accordance with a phase of the invention, the required frozen mercury powder particles are produced by atomizing liquid mercury which has been precooled to near freezing in the manner described above with a stream of supercooled liquid which is supercooled to a temperature considerably below the freezing temperature of mercury. The supercooled atomizing liquid is discharged with high velocity through a nozzle to which the precooled liquid mercury is delivered so that the high velocity supercooled atomizing liquid causes the dispersion of the precooled liquid mercury as it passes through the atomizing nozzle. As in the atomizing process described above, the atomized frozen mercury powder particles are discharged into a supercooled liquid maintained at a temperature considerably below the temperature of frozen mercury so that the individual particles of the frozen mercury powder are individually enveloped and kept separated by films of the storing liquid which suppresses any tendency of the individual frozen mercury particles to merge or agglomerate.

Solid carbon dioxide sublimes into gas at −78.5° C. Accordingly, when carbon dioxide gas is used for atomizing the precooled mercury, the carbon dioxide gas may be cooled to a temperature much lower than −40° C., the freezing temperature of mercury. Nitrogen or helium gas may be precooled to very low temperatures for use as an atomizing gas, the freezing point of the two gases being −209° C. and −272.2° C., respectively.

The following liquids may be precooled to temperatures considerably below the temperature of frozen mercury for use as an atomizing liquid or as a storing liquid for atomizing and/or storing the atomized frozen mercury powder particles.

Chemical Name	Trade Name	Freezing Temperature ° C.
Dichlorotetrofluoroethane	Freon 114	−95
Acetone		−95
Monochloropentafluoroethane	Freon 115	−106
Trichloromonofluoromethane	Freon 11	−111
Dichloromonofluoromethane	Freon 21	−135
Dichlorodifluoromethane	Freon 12	−158
Monochlorodifluoromethane	Freon 22	−160
Monochlorotrifluoromethane	Freon 13	−181
Tetrafluoromethane	Freon 14	−184
Nitrogen		−209
Helium		−272.2

There will now be described, by way of example, one form of arrangement for atomizing precooled liquid mercury which is near freezing into frozen mercury powder particles which are maintained in powder form ready for use in practicing the invention, the drawing showing in diagrammatic form the general arrangement of an equipment suitable for this purpose. It comprises a vessel structure generally designated **20** containing an inner vessel **21** which is cooled by any conventional refrigerating or cooling equipment surrounding or associated with it so as to maintain its interior vessel space at a supercooled temperature considerably below the normal freezing temperature of mercury. A body of supercooled storing liquid **22** is arranged to be retained within the vessel at a suitable level indicated at **22–1**. The storing liquid **22** is maintained at a desired sub-cool temperature considerably below the freezing temperature of mercury either by circulating it through a suitable refrigerating system not shown or by circulating a supercooled refrigerant fluid through pipes (not shown) immersed in the storing liquid **22**.

In the inner part of the vessel **21** there is mounted a discharge duct **31** terminating in a discharge nozzle **32** having a discharge opening **33** for discharging therethrough a thin stream of precooled liquid mercury maintained near its freezing temperature. The precooled liquid mercury is supplied to the discharge duct **31** by a supply duct **34** suitably enclosed by a heat insulating enclosure **34–1** to assure that mercury of the desired precooled temperature slightly above or near its freezing temperature will flow through the discharge duct **31** into the discharge nozzle opening **33**.

The liquid mercury discharge duct **31** is combined with an atomizing fluid discharge duct **41** provided with a discharge nozzle opening **43** arranged to discharge the atomizing fluid with sufficiently high velocity by way of the mercury discharge nozzle opening **33** for causing the atomizing fluid to disperse the stream of precooled liquid mercury into atomized mercury particles which are frozen as they are being atomized. Such freezing of the frozen atomized mercury particles may be secured either by discharging them through the nozzle opening **33** with an atomizing fluid of sufficient volume and sufficiently low temperature to provide a temperature gradient and heat capacity differential which are sufficient for securing by heat exchange the freezing of the precooled atomized mercury particles as they are discharged into the vessel space **20–1**.

Alternatively, or in combination with the foregoing procedure, the desired freezing of the atomized mercury particles may be effected by discharging them in atomized form into the body of the supercooled storing liquid **22** within the vessel **21** for causing the atomized powder particles entering the surface of the liquid body **22** to be instantaneously frozen into discrete mercury powder particles.

As a further alternative and in combination with the foregoing procedures, the desired freezing of the atomized mercury particles may be effected by discharging them in atomized form onto a large guide surface structure of solid material which is maintained at a very low temperature so that the atomized mercury powder particles reaching the guide structure are instantly frozen and guided thereover in frozen form into the supercooled storing liquid.

In accordance with a phase of the invention, an atomizing liquid for atomizing the precooled stream of mercury is utilized to form around the individual atomized mercury particles a film or envelope of the atomizing liquid which is frozen together with the mercury particles enveloped thereby giving the individual frozen atomized mercury powder particles a protective frozen film enclosure of atomizing liquid which is effective in suppressing merging or conglomeration of the atomized frozen mercury particles. The atomizing liquid used for this purpose may be so chosen that when the frozen mercury powder particles are in a subsequent compacting stage compacted into the desired solid frozen mercury pattern, the compacting process is carried on at a temperature at which the protective film envelope of the mercury powder particles becomes liquefied and squeezed out or ejected from the die as the body of the frozen mercury particles is compacted therein into the desired solid frozen mercury pattern.

Acetone is a very effective liquid for securing combined

atomizing action and formation of protective films around the individual powder particles in which case a storing liquid of lower freezing temperature such as Freon 21 or Freon 22 is utilized as the storing fluid **22**. Alternatively, any of the other liquids given in the table above, which remain liquid at temperatures lower than the freezing temperature of acetone, may be used as the storing liquid **22**. However, the other liquids listed in the table which have a freezing temperature in the range up to about 150° C., may be used as a film-forming atomizing liquid in the same manner as acetone, whereas liquids having a suitably higher freezing temperature are utilized as the storing liquid.

As explained above, instead of discharging the atomized mercury powder particles from the nozzle **32** directly into the supercooled storing liquid **22**, the stream of atomized nearly frozen mercury powder particles may be discharged by the nozzle **32** onto a supercooled guide surface structure arranged to assure that the atomized mercury powder particles reaching the guide structure are instantly frozen and guided thereover as a frozen mercury powder into the supercooled storing liquid.

The drawing shows how the atomizing equipment thereof may be combined with such supercooled guide structure **35** of the invention. The guide structure **35** is shown in the form of a generally curved guide or baffle wall having side walls **37** shaped and arranged to intercept the stream of atomized mercury powder particles discharged from the nozzle **32** and to instantaneously freeze all atomized mercury particles reaching the same and to deflect and guide the atomized and frozen mercury powder particles into the supercooled body of storing liquid **22** filling the lower region of the vessel **21**.

The guide wall structure **35** is shown formed as a double walled hollow guide body of suitable metal, such as stainless steel, and is arranged to circulate through its hollow interior space **35–1** a supercooled liquid, such as liquid nitrogen for assuring that the guide structure or baffle wall **35** is at all times maintained at a low temperature which causes liquid atomized mercury particles discharged thereon by the nozzle **32** to become instantaneously frozen into frozen mercury powder particles. The hollow space **35–1** of the guide structure **37** is suitably connected, as by circulating ducts **39** with a refrigerating circuit for circulating properly supercooled liquid of the required low temperature through the hollow guide structure **35**.

In many cases, it is very difficult or impossible to produce by the process of the invention a frozen mercury pattern of a complicated object, such as a bucket, with a simple compacting die because it is difficult or impossible to withdraw the frozen mercury from the cavity space of the opened die without distorting the shape of the desired pattern.

To meet this difficulty, advantage is taken of the fact that frozen mercury parts at temperatures within the range from about 30° to 40° C. below the freezing point weld or unite readily into a single composite unit when brought into contact with each other along mating surfaces. This makes it possible to produce frozen mercury patterns of complicated objects by first preparing with the process of the invention simple frozen sectional parts of the desired complete frozen mercury pattern with individual compacting dies for such pattern sections. Thereafter the so formed frozen mercury pattern sections are brought into contact along their mating surfaces along which they immediately weld into the desired composite pattern having the shape of the desired complicated article to be cast. Thus, for example, a frozen mercury pattern of a hollow gas turbine bucket may be produced out of two or more frozen mercury pattern sections which are thereafter joined to each other along mating surfaces into an integral complete frozen mercury pattern having the shape of the desired hollow gas turbine buckets. Several separate frozen mercury bucket pattern sections when brought together along their mating surfaces will instantly weld into an integral frozen mercury pattern having the shape of the desired hollow gas turbine buckets.

A plurality of so produced separate frozen mercury patterns of complicated objects prepared from frozen mercury powder in the manner described above may be readily joined into an integral multiple pattern cluster which is used for forming a mold with a mold cavity of the shape of the pattern cluster into which hot metal may be cast for producing a metal casting having the shape of the pattern cluster. Such frozen mercury multiple pattern cluster may be formed as follows. A row of frozen mercury bucket patterns is joined by contact welding to a plurality of lateral sprue branches of frozen mercury. The several sprue branches of frozen mercury carrying the frozen mercury bucket patterns united thereto are then joined to a main vertical sprue stem of frozen mercury which is provided at its upper end with an enlarged gate section holding anchored therein a metallic hook, of material such as steel, for use in handling the pattern cluster while it is used for forming around it the desired mold.

Such frozen mercury pattern cluster is then used for forming the mold, for instance, in the form of a thin porous shell mold.

An important feature of the present invention, is the fact that it makes it possible to use, what are known as fusible metals, which are relatively soft, and readily machined as cast, for producing the compacting dies with which the frozen mercury powder is compacted into the desired casting pattern. Among such metals are, by way of example, Woods metal which melts at about 70° C., consisting 7 to 8 parts bismuth, 4 lead, 2 tin and 1 to 2 parts cadmium; alloy of 50% bismuth, 25% tin, 25% cadmium which melts at about 93° C.; alloy of 3 parts cadmium, 4% tin, 15% bismuth, and 8% lead which melts at about 70° C.; alloys of 8 parts bismuth 5 to 30 parts lead and 3 to 24 parts tin which melt at temperatures from about 100° C. to 170° C.; alloy of 27% lead, 13% tin, 50% bismuth and 10% cadmium which melts at 60° C.; also such alloys of lead, tin and cadmium which melt at temperatures in the range of 150° C. to 330° C. (Throughout the specification and claims all proportions are given in weight unless specifically stated otherwise.) Dies made of such metal, which are cooled, prior to the compacting process, to a temperature of about 5° to 10° C. or more below the freezing temperature of the frozen mercury powder, exhibit at such low temperature the great physical strength which makes them suitable for compacting the frozen mercury powder into the desired accurately shaped casting pattern.

The features and principles underlying the invention described above in connection with specific exemplifications, will suggest to those skilled in the art many other modifications thereof. It is accordingly desired that the appended claims be construed broadly and that they shall not be limited to the specific details shown and described in connection with exemplifications thereof.

I claim:

1. In the process of forming an impermanent pattern of frozen mercury for the preparation of a precision mold of a shaped object to be cast, the procedure of atomizing liquid mercury which is near its freezing temperature into fine atomized mercury particles, freezing the so-atomized liquid mercury particles into a mass of frozen mercury powder particles, and thereafter compacting a mass of said frozen mercury powder particles in a shaped cavity of a compacting die maintained below the freezing temperature of mercury so as to form out of said mass of frozen mercury powder particles a shaped frozen mercury pattern of the object to the cast.

2. In the process of forming an impermanent pattern of frozen mercury for the preparation of a precision mold of a shaped object to be cast, the procedure of atomizing liquid mercury which is near its freezing temperature into

fine atomized mercury particles, freezing the so-atomized liquid mercury particles into a mass of frozen mercury powder particles, applying to the atomized mercury particles a liquid substance which is of a temperature below the freezing temperature of mercury and which has the property of adhering as a coating to said frozen mercury powder particles and causing the individual frozen mercury powder particles to have an adhering exterior coating of said substance, and thereafter compacting a mass of said frozen mercury powder particles having a coating of said substance in a shaped cavity of a compacting die maintained at an intermediate temperature below the freezing temperature of mercury and above the freezing temperature of said substance so as to form out of said mass of coated frozen mercury powder particles a shaped frozen mercury pattern of the object to be cast while squeezing out the liquid coating substance from the compacted body of the frozen coated mercury powder particles.

3. In the process of forming an impermanent pattern of frozen mercury for the preparation of a precision mold of a shaped object to be cast, the procedure of atomizing liquid mercury which is near its freezing temperature into fine atomized mercury particles, freezing the so-atomized liquid mercury particles into a mass of frozen mercury powder particles, applying to the atomized mercury particles a liquid substance selected from the group consisting of acetone, dichlorotetrafluoroethane, monochloropentafluoromethane, trichloromonofluoromethane, dichloromonofluoromethane, monochlorodifluoromethane, monochlorotrifluoromethane and tetrafluoromethane which is of a temperature below the freezing temperature of mercury and which has the property of adhering as a coating to said frozen mercury powder particles and causing the individual frozen mercury powder particles to have an adhering exterior coating of said substance, and thereafter compacting a mass of said frozen mercury powder particles having a coating of said substance in a shaped cavity of a compacting die maintained at an intermediate temperature below the freezing temperature of mercury and above the freezing temperature of said

substance so as to form out of said mass of coated frozen mercury powder particles a shaped frozen mercury pattern of the object to be cast while squeezing out the liquid coating substance from the compacted body of the frozen coated mercury powder particles.

4. In the process as claimed in claim 2, wherein the mass of frozen mercury powder particles with their surface coatings adhering thereto are, prior to compacting in the compacting die, deposited in a storing liquid which is maintained below the freezing temperature of mercury and from which storing liquid they are transferred into the cavity of the compacting die.

5. In the process as claimed in claim 4, wherein said storing liquid is maintained at a temperature below the freezing temperature of the coating substance applied to the frozen mercury particles.

6. In the process as claimed in claim 3, wherein the mass of frozen mercury powder particles with their surfaces coatings adhering thereto are, prior to compacting in the compacting die, deposited in a storing liquid which is maintained below the freezing temperature of mercury and from which storing liquid they are transferred into the cavity of the compacting die.

7. In the process as claimed in claim 6, wherein said storing liquid is maintained at a temperature below the freezing temperature of the coating substance applied to the frozen mercury particles.

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