March 2, 1965 E. J. MELLEN, JR., ETAL 3,171,174

FROZEN-MERCURY PROCESS FOR MAKING SHELL MOLDS

Filed June 6, 1963 4 Sheets-Sheet 1

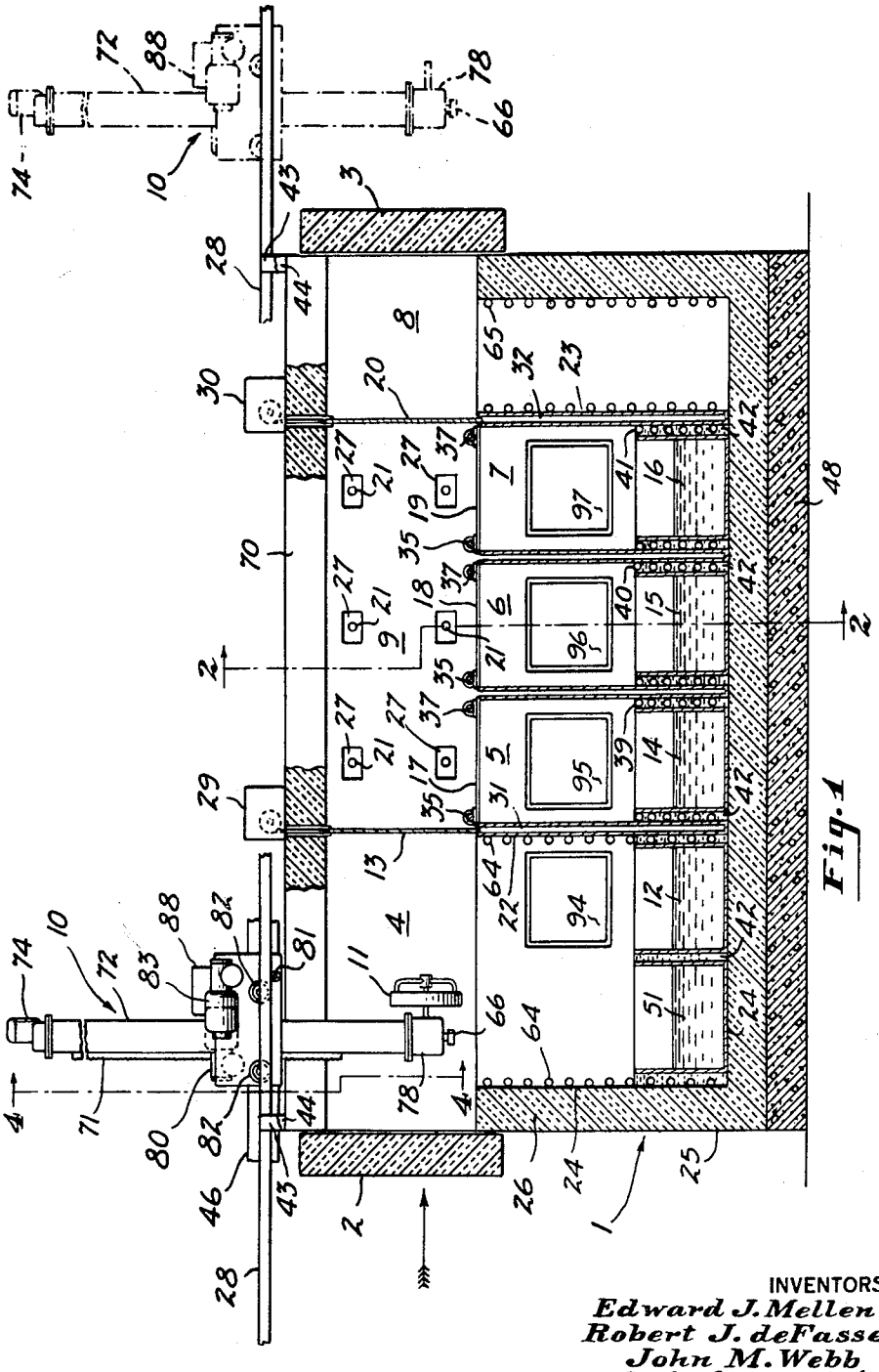


Fig. 1

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FROZEN-MERCURY PROCESS FOR MAKING SHELL MOLDS

Filed June 6, 1963 4 Sheets-Sheet 2

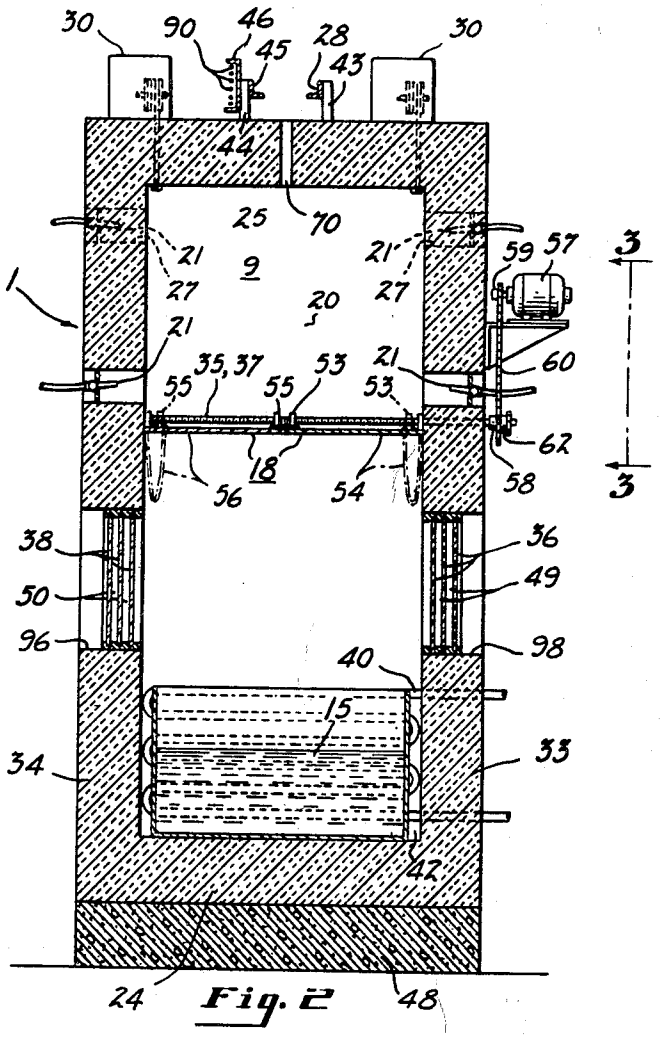


Fig. 2

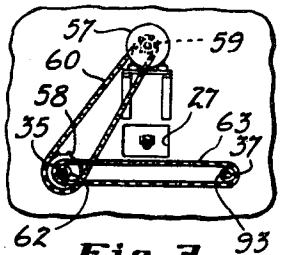


Fig. 3

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FROZEN-MERCURY PROCESS FOR MAKING SHELL MOLDS

Filed June 6, 1963 4 Sheets-Sheet 3

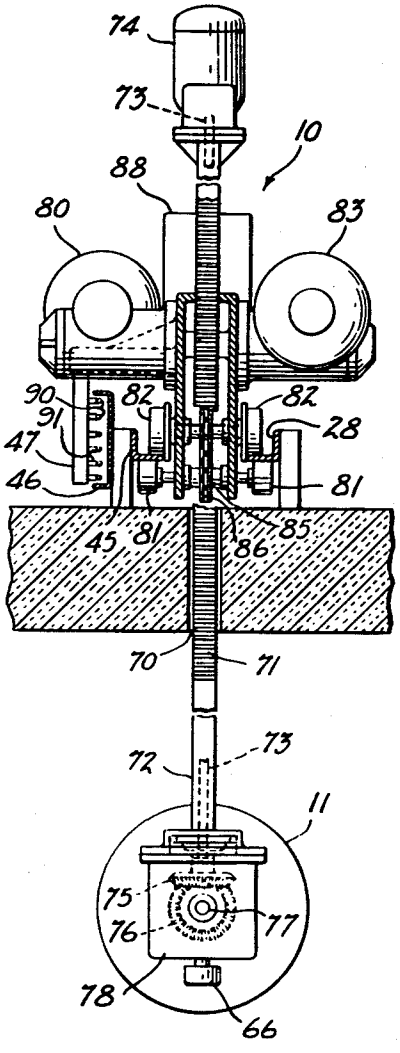


Fig. 4

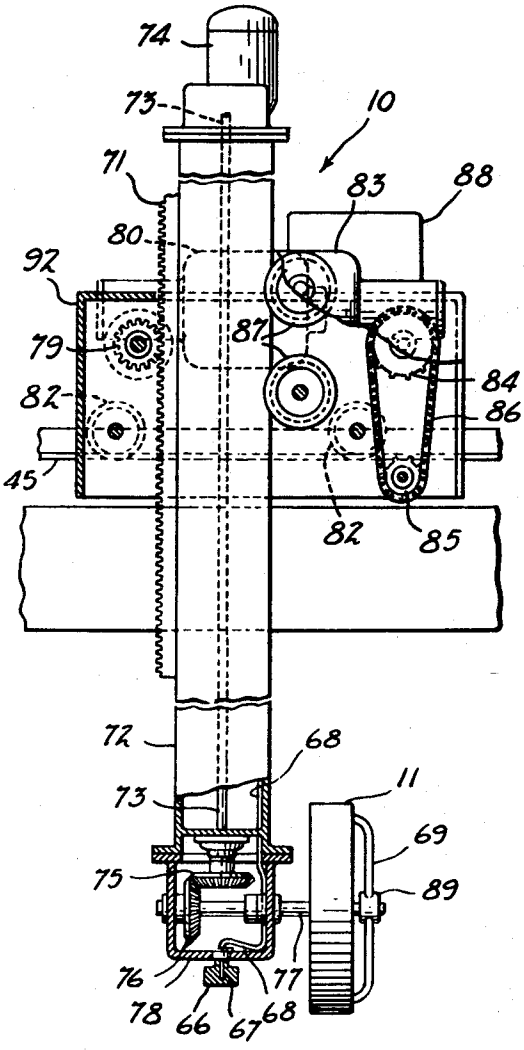


Fig. 5

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FROZEN-MERCURY PROCESS FOR MAKING SHELL MOLDS

Filed June 6, 1963 4 Sheets-Sheet 4

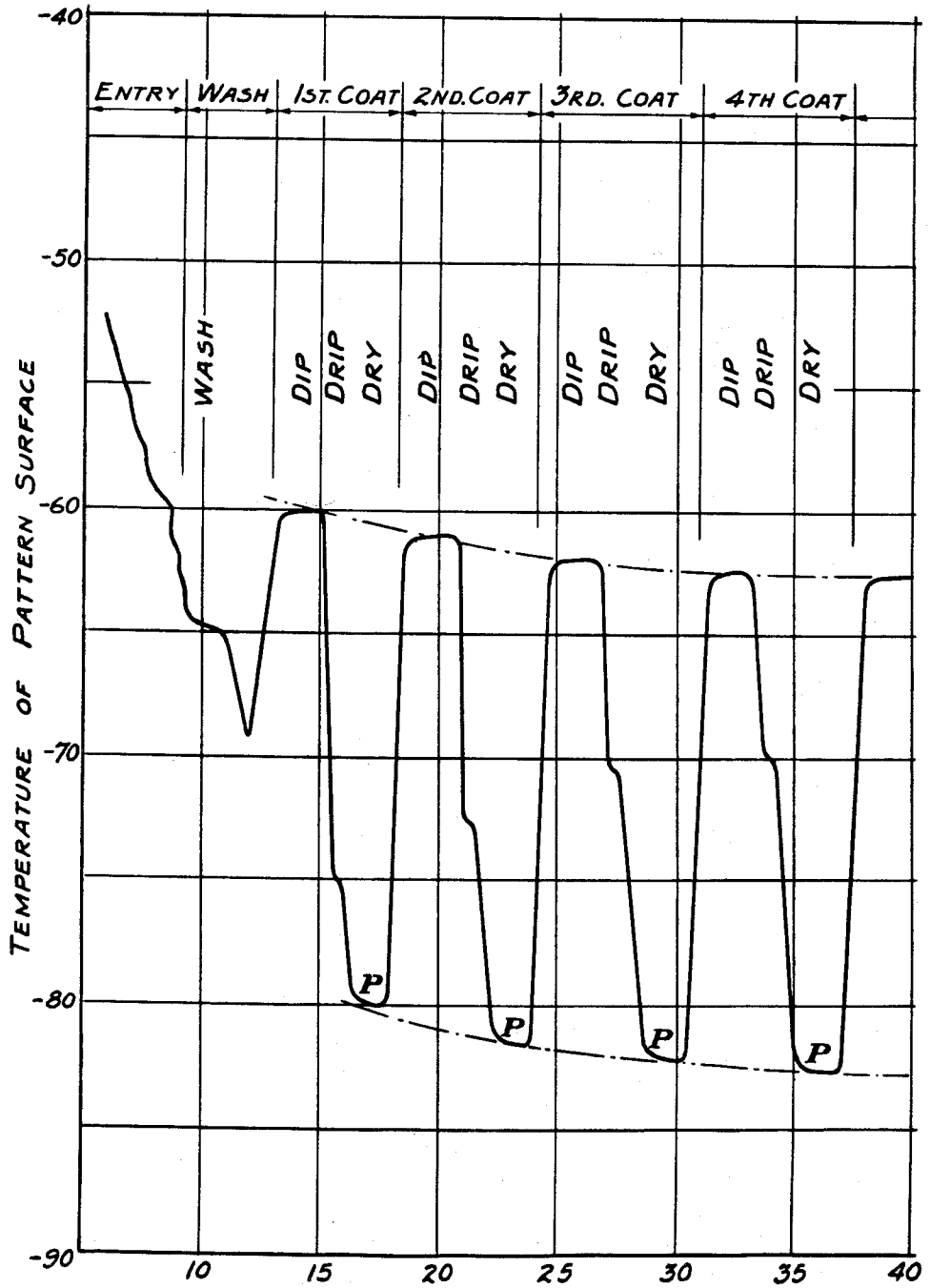


Fig. 6

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United States Patent Office

3,171,174

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3,171,174
FROZEN-MERCURY PROCESS FOR MAKING SHELL MOLDS

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Filed June 6, 1963, Ser. No. 286,010
10 Claims. (Cl. 22—196)

The present invention relates to an improved process and apparatus for forming shell molds from frozen mercury patterns.

The frozen-mercury casting process has been in use for more than a decade and is described in several patents granted to Everard F. Kohl, such as United States Patent No. 2,820,268. As now practiced, this "open-box" process is characterized by a low production rate and a procedure which depends, to a considerable extent, upon hand labor and individual judgment. The frozen-mercury patterns are hand dipped in open dip baths and dried according to the operator's visual judgment and experience. The atmosphere surrounding the dip baths is not controlled. Under certain conditions, water vapor and foreign gases, such as carbon dioxide, are absorbed in the dip baths and are trapped in the ceramic material and on the interfaces between the successive layers of the shell mold. As a result, some pattern jobs, and in particular the larger jobs, have been plagued by a high incidence of weak, unstable molds.

In order to obtain shell molds having the desired high quality using such procedures, the temperatures in the drying zones were maintained at —60° F. or below and preferably not in excess of —70° F. Higher drying temperatures below the melting point of mercury (i.e., —50° F.) were found to produce inferior shell molds and were, therefore, avoided. The drying temperature was not only maintained substantially below the melting point of the mercury, as suggested in said Kohl Patent No. 2,820,268, but was far below —50° F. (see Patent No. 2,857,641).

When using the "open-box" process described above, any increase in the drying temperature above —60° F. was considered to produce a proportionate decrease in the quality of the shell molds. It has now been discovered that, by using a radically different process wherein the atmosphere is controlled and the dew point is maintained at a very low level, high quality shell molds can be produced in a more reliable manner using drying temperatures substantially higher than the freezing point of the mercury patterns (or example, —10° F. to +30° F.). The new process provides molds of uniformly higher quality than those produced by the conventional "open-box" process while increasing the rate of production and thus involves a great step forward in the frozen-mercury casting art.

An object of the present invention is to provide an apparatus and a process for forming shell molds on frozen mercury patterns which does not necessitate a large amount of hand labor, is accurately controlled, and has a high production rate.

Other objects and advantages will appear from the following description and drawings, in which like numerals relate to like parts.

FIGURE 1 is a side elevation view, mostly in cross section, of the apparatus of the present invention;

FIGURE 2 is an end view in cross section taken through line 2—2 of FIGURE 1, the retracted positions of the flexible covers being shown in dot-dash lines;

FIGURE 3 is a side elevation view of the apparatus of FIGURE 1 showing the motor and belt drive for operating the seal-off covers over the dip chambers;

FIGURE 4 is an end view, partially in cross section, of the mold conveyor means;

FIGURE 5 is a side view, partially in cross section of the mold conveyor means; and

FIGURE 6 is a graph with descriptive material showing the temperature of the pattern surface plotted against elapsed time in the present process.

In accordance with the present invention, a large thermally insulated enclosure **1** is divided into a series of chambers. The chambers are sealed off from one another by seal-off doors or closure means which open and close as desired and which will be hereinafter described. Referring to FIGURE 1, the unit essentially comprises an entry chamber **4**, a prime dip chamber **5**, a standby dip chamber **6**, a concrete dip chamber **7**, a drying zone **9** disposed over the dip chambers, and an exit chamber **8**. A conveyor means **10** carries the pattern **11** through the unit and is adapted to travel horizontally back and forth through the unit and move the pattern vertically up and down as required.

It should be borne in mind that the various frozen mercury pattern materials go from the solid to liquid state at around —38° F. and soften at slightly lower temperatures. For this reason, the entry chamber, dip chambers, exit chambers and various wash and dip baths must all be maintained at around —50° F. or below.

The pattern or mold **11** is individually cast by freezing mercury in steel molds. It may also be formed by "booking" or pressing together components of frozen mercury. To make the pattern or components of the pattern, liquid mercury is poured into a steel mold and the assembly is emmersed in a container of acetone and Dry Ice at temperatures ranging from —70° F. to —100° F. to freeze up the mercury. Handling rods and hooks and sometimes lightening members are placed in the pattern prior to freezing.

After the pattern has been formed, it is attached to the conveyor means **10** and introduced into the entry chamber **4** through entry door **2** of the unit. In the entry chamber, the pattern is first dipped in an acetone bath **51** to remove the frost from the surface thereof and then washed in a bath **12** of "refrigerant **22**." Refrigerant **22** is known as "Freon 22" and is chemically identified as liquid monochlorodifluoromethane. The pattern is then transported from the entry zone, through sliding door **13**, the drying zone **9**, and through sliding door **17** into the prime dip chamber **5** where it is dipped in the prime dip bath **14**. This bath comprises a slurry of refractory materials, binder, and a liquid vehicle, such as refrigerant **22**, and may be kept at temperatures of from —50° F. to —90° F. The pattern is removed from the prime dip **14**, held over the dip bath for a short time (i.e., from 5 seconds to a few minutes) to allow surplus slurry from the dip bath to drip back into the dip bath, and then elevated into the drying chamber **9**.

When the pattern is introduced into the drying zone, the surface temperature rapidly depresses as the refrigerant **22** evaporates. At a temperature of about —80° F. to —100° F., a plateau or point in the nature of an equilibrium is reached between the drying atmosphere and the vapor pressure of refrigerant **22** in the slurry mixture on the pattern surface. In this drying step, the temperature of the pattern surface approaches the wet-bulb temperature of the refrigerant which is evaporating therefrom. As the mass of the pattern and amount of refrigerant to be evaporated increases, the ultimate temperature of the pattern surface decreases. This is shown in the graph of FIGURE 6 in which the plateaus referred to above are designated by the letter P. After the first dip, the temperature of the pattern surface stays at approximately —80° F. so long as the refrigerant **22** is evaporating therefrom. When substantially all of the refrigerant **22** has

evaporated, the surface temperature of the pattern immediately starts to rise toward the dry bulb temperature of the drying chamber. As soon as this starts to happen, however, the pattern is removed from the drying chamber and promptly immersed in the next dip.

Since the atmosphere over the dip baths has a relatively high proportion of refrigerant **22** vapor in it and is not controlled, the slurry on the pattern surface does not begin to evaporate or dry at a rapid rate until the pattern is placed in the drying chamber. Once it is placed in the drying chamber, however, it evaporates at a relatively rapid rate. This rate can be controlled by varying the dry bulb temperature and the dew point of the drying chamber **9**. The air in the drying chamber is dehumidified to a dew point of below —50° F., and the preferable dew point of the entering air is from —60° F. to —80° F., the point of course being the aqueous dew point. The dry bulb temperature of the air in the drying chamber **9** is usually materially higher than the softening temperature of the mercury pattern or the freezing point of mercury (i.e., at least —20° F.) and is preferably from —10° F. to +30° F.

A pattern may be given from four to twenty dips in the prime dip and from five to ten dips in the concrete dip. Any number of dips and separate dip chambers may be provided as advisable for the particular molds being manufactured. After each dipping operation the pattern is dried in the drying chamber. When a suitable number of layers of refractory material has been deposited upon the surface of the pattern to form a shell mold, the pattern is transported into the exit zone **8** and stored therein, if necessary, or removed from the cabinet through exit door **3**.

In the final steps, the pattern is heated up and the mercury liquefied and drained therefrom leaving the green shell mold. This green shell mold is fired to fuse it into a tough ceramic material capable of withstanding high temperatures of molten metal.

Referring to FIGURE 1, the thermally insulated unit **1** consists of inner and outer shells **24** and **25** which are sealed as tightly as possible and have a minimum of openings. Insulating material **26** is disposed between the shells. The thickness of the unit should preferably be such that the outside shell temperature will be within 10° F. of the maximum room temperature. This will preclude the formation of dew on the outside shell. A suitable insulating material is foamed-in-place polyurethane. The unit may be rectangular in shape, as shown, or of other shapes as desired such as a circular one. In circular units and perhaps others, the entry and exit chambers may be combined into a single chamber.

The unit shown in FIGURE 1 is provided with an entry door **2** and an exit door **3**. The entry and exit doors **2** and **3** are arranged high in the cabinet to minimize the loss of the colder atmosphere from the cabinet. The first chamber is the entry chamber **4**. This chamber has an acetone bath **51** and a refrigerant bath **12**, the purpose of the acetone bath being to wash off frost on the pattern surface and the purpose of the refrigerant **22** bath being to wash off the acetone. An ethyl alcohol bath may be used in place of the acetone and other washes such as "refrigerant **13**" may be used in place of refrigerant **22**, all of which is well known in the art. If desired, the pattern may be washed off in a single dip bath of refrigerant **22** or the like instead of being initially immersed in acetone. The baths **51** and **12** are preferably maintained at temperatures of about —50° F. or below. Refrigerating coils line the walls of the entry chamber and surround both baths. In order to assist in heat transfer, the coils around the baths are immersed in ethyl alcohol at **42**.

Seal-off door **13** separates the entry chamber from the drying zone **9**. This door is operated by a motor **29** mounted on the roof of the unit. For opening, the door is lowered into the slot **31** in the partition **22** and for closing it is lifted out of the slot as shown in FIGURE 1.

The drying chamber or zone **9** is provided with nozzles **21** mounted in conduits **27**. Air at dry bulb temperatures of from —10° F. to +30° F. is introduced into this chamber through these nozzles **21**. The nozzles are preferably located in upper and lower rows as shown in FIGURE 1 and are directed at the approximate location of the pattern when it is being held in the drying chamber. There are no specific air outlets and natural leakage of air out of the system is relied upon as the air exhaust system. This, of course, means that the pressure of the unit should be maintained at slightly above atmospheric and any air leakage will be outward from the interior of the unit to the surrounding atmosphere rather than in the opposite direction.

A cover **17** is provided to seal off the prime dip chamber from the dry air chamber. This cover opens and shuts as hereinafter described. The prime dip chamber contains a prime dip **14** which is surrounded by refrigerating coils **39** which, in turn, are immersed in ethyl alcohol at **42** or other heat transfer medium liquid at temperature below —50° F. The temperature of the prime dip bath is preferably —55° F. or below. The prime dip bath may be any conventional prime dip used in the frozen mercury process.

A suitable prime dip is:

	Parts by weight
Refrigerant **22** (liquid monochlorodifluoromethane)	10,500.00
Polymerized vinyl acetate having a viscosity of 700 to 900 centipoises at 20° C. with molar solution in benzene	81.0
Phenol-formaldehyde resin condensation product condensed to its intermediate stage or "B" stage which is soluble in refrigerant **22**	94.5
Sodium fluoride	54.8
Boric acid	18.2
Zirconium silicate—325 mesh particle size	7,923.7

Next to the prime dip chamber is a standby dip chamber **6** provided with a standby dip **15**. The standby dip may be similar to the prime dip or the concrete dip or may be slightly different from each, depending upon the particular type of shell mold being formed. A standby dip is desirable but not necessary, it being possible to operate with prime dip and concrete dip chambers only. Refrigerating coils **40** immersed in ethyl alcohol at **42** keep the standby dip at a suitable temperature, which is preferably below —55° F.

The standby dip chamber is sealed off from the drying zone by a curtain or cover **18**. This is shown in more detail in FIGURES 2 and 3. Each of the covers **17**, **18** and **19** comprises on each side of the chamber, two flexible half portions **54** and **56** which are moved back and forth by screws. Motor **57** drives small sprocket **59** connected to large sprocket **58** through chain **60**. Small sprocket **93** in turn drives the corresponding screw through sprocket **62** and chain **63**. This arrangement is shown in FIGURE 3. The operating mechanisms for covers or doors **17**, **18** and **19** are the same. When a multiplicity of dips are employed, it is contemplated that one cover may be used over two or more dips as the dipping and drying cycle warrants.

Screws **52** have a right-hand thread for half of their length and a left-hand thread for the other half of their length. The ends of the covers **54** and **56** are attached to nuts **53** and **55** which travel back and forth when the screw is rotated.

The standby dip chamber **6** may also be provided with observation windows **96** and **98** as shown. These windows comprise three panes of glass **36** and **38**, respectively, with two evacuated spaces **49** and **50** formed therebetween. The entry prime dip and concrete dip chambers may likewise be provided with similar windows **94**, **95** and **97** as shown.

Next to the standby dip chamber **6** is the concrete dip chamber **7**. This chamber has a concrete dip bath **16** therein and is sealed off from the drying chamber by cover **19**. The dip bath is surrounded by refrigerating coils **41** which are immersed in ethyl alcohol **42**. As with the prime dip, the concrete dip generally comprises a vehicle, such as refrigerant **22**, a binder, and refractory materials. A conventional concrete dip formulation is:

	Parts by weight
Refrigerant **22**	18,000.00
Vinyl acetate polymer having a viscosity of 900 centipoises at 20° C. with molar solution in benzene	400.00
Ethyl cellulose, ethylated to from 46.5% to 48.5% and a 5% solution of which in 80% toluene and 20% ethyl alcohol has a viscosity of 20 centipoises	132.00
Phenol-formaldehyde resin condensation product condensed to its intermediate stage or "B" stage which is soluble in refrigerant **22**	148.00
Primary ammonium phosphate	500.00
Zirconium silicate —325 mesh particle size	23,952.00
Aluminum silicate (mullite) from —14 mesh to +35 mesh particle size	14,568.00

Refrigerants which may be used as the slurry vehicle instead of refrigerant **22** include dichloro-difluoromethane, trichloro-monofluoromethane, dichloromethane, and bromotrifluoromethane.

Sliding door **20** seals off the drying chamber **9** from the exit chamber **8**. This door is operated by motor lift means **30** and disappears into the slot **32** formed in the partition **23** between the exit chamber and concrete dip chamber. The exit chamber **8** is similar to the entry chamber and is cooled by refrigerating coil **65** mounted in the walls. Patterns pass out of the chamber through exit door **3**. The exit chamber may also be used as a pattern storage chamber where patterns may be kept after dipping until they are needed.

Every effort should be made to keep the various compartments sealed off from each other and from the outside atmosphere. As the patterns are transported from chamber to chamber, the seal-off doors and covers are opened and closed. The entry door **2** should not be opened at the same time as the seal-off door **13** because of loss of dehumidified air. The same applies to exit door **3** and seal-off door **20**. If desired, suction fans or air scoops may be located outside the entry door **2** and exit door **3** of the enclosure **1** to draw in the air escaping from the enclosure through these doors as they are opened and closed. By recycling and processing this air, the Freon gas may be recovered from it.

The mercury pattern or mold **11** is carried on mold conveyor means **10** as best shown in FIGURES 4 and 5. The mold is attached to the mold pattern shaft **77** by bolting the bushing **89** in the mold to the shaft. Gear **76** rotates the mold pattern shaft **77** and in turn rotates the mold to provide an even distribution of dip material thereon. Gear **75** powered by rotor motor **74** through the shaft **73** drives the mold pattern rotating gear **76**. The gear assembly is mounted in housing **78**. If desired, the gear arrangement can be designed to provide both a rotation of the mold on a vertical, horizontal or tilted intermediate positions of the axis to provide more uniform distribution of the dip over the pattern.

The pattern is preferably rotated continuously throughout the process of the present invention, particularly throughout the period when it is immersed in the dip tanks so that there is an even distribution of slurry and there are no trapped air pockets. When the mold is rotated during the dipping process, the mold does not have to be immersed all the way into the dip tank but instead can be immersed about half-way. This is the preferable procedure because a percent of the refrigerant in the slurry evaporates and a heavier coating can thus be applied in a

single dip. The speed of rotation is in the order of 1 to 10 r.p.m. For the best results, the direction of rotation should be reversed at regular intervals.

Rotor drive shaft housing **72** houses the rotor drive shaft **73**. One side of the drive shaft housing is provided with a rack **71** which is driven by spur gear **79** to raise and lower the unit. Rubber guide or idler wheels **87** (see FIGURE 5) assist in positioning the housing **72** as it is moved vertically by the gear **79**. A spur gear **79** is driven by motor **80**. This arrangement allows the unit to be lifted up and down vertically and in and out of dip baths as required.

In order to propel the unit horizontally along the tracks **28** and **45**, motor **83** drives rubber drive wheels **81** which bear on the underside of the tracks through sprockets **85** and **84** and chain **86**. The wheels **82** engage the tracks to support the unit as shown in FIGURES 4 and 5. The power to operate the unit comes in through power lines **90** contained in the channel or conduit **46**. Power take-off shoes **91** are mounted in a depending unit **47** and are kept in contact with the power lines **90**. The controls for the various motors are carried on the unit in control box **88**. The whole is mounted in a housing **92**. The rails **28** and **45** are supported at spaced intervals by vertical supports **43** and **44**.

The controls for the conveyor means are mounted on the conveyor in control box **88**. If desired, separate hand controls may be used which travel along with the conveyor means and are operated by a control button carried in the hand and attached to the unit. In the alternative, mechanical arms mounted in the wall of the unit may be employed to manipulate the molds from the dip baths into the drying chamber and from one dip bath into the other. Mechanical arms of a similar nature are currently employed in the handling of radioactive materials. The use of mechanical arms and manipulating means would naturally eliminate some or all of the mold conveying and rotating means, depending upon the particular installation.

It is also possible to install television cameras at various points inside of the unit to supplement or replace the observation windows.

In fabricating the mold, the mercury is poured around a spider or lightening unit **69** provided with a central hub **89**. The mercury solidifies around the spider **69** and becomes integral therewith when the unit has frozen solid. As noted, the pattern is bolted onto the shaft **77** through the bushing **89**.

The means for refrigerating the unit is located outside the unit and has not been shown. A cascade or step-down refrigeration system is preferably employed. In this system, the temperature of a first refrigerant is taken down to approximately —20° F. This is used to cool a second refrigerant in a cascade condenser and the second refrigerant is then pumped into the coils surrounding the dip tanks to maintain them at temperatures below —50° F. The same refrigerant is also pumped through the coils surrounding the entry and exit chambers to keep these chambers at suitably low temperatures.

An accurate check on the surface temperature of the pattern is maintained by use of a frozen mercury button **66** mounted on the bottom of the gear housing **78** into which a thermocouple **67** is placed. The thermocouple lead **68** goes back up through the conveyor housing **72** to the control panel. In the alternative, a thermocouple can be mounted in the pattern itself.

One of the features of the present invention is the fact that for some jobs refrigerant **11** (trichloromonofluoromethane) may be used as the slurry vehicle in place of refrigerant **22** as well as other refrigerants previously noted.

The frozen-mercury process of this invention can substantially increase the rate of production of shell molds. If, for example, 10 coats are applied to the mercury pattern to form the shell mold, the total time for apply-

ing said coats might be 45 minutes or less as compared to about 5 hours for the conventional Kohl process. In applying each of the ten coats, according to the invention, the mercury pattern may, for example, be (1) dipped for 45 seconds in a ceramic slurry maintained at about −90° F., (2) raised to an intermediate zone directly above the dip tank having a temperature of around −40° F. and held in said intermediate position for 5 seconds to permit opening of the sliding door (i.e., **17**, **18** or **19**) separating said intermediate zone from the drying zone, (3) raised into the drying zone, which has a dry bulb temperautre of −5° F. to 0° F. and a dew point in the neighborhood of −80° F., and maintained in said drying zone for 85 seconds, (4) lowered into an intermediate zone which has a temperature of around −40° F., and maintained in said intermediate zone for 120 seconds, and (5) again lowered into the ceramic slurry. Thus, the total time for applying one coat to the shell mold would be less than 4.5 minutes. After the tenth coat, the frozen mercury pattern with the shell mold thereon may be held for 2 hours in the exit zone which is maintained at around −50° F. Thus, the total time for forming such a high quality shell mold would be about 2.7 hours.

FIGURE 6 is a graph illustrating the process of the present invention. The temperature of the pattern surface is recorded against elapsed time. The average dip temperature for this series of runs was −60° F. The approximate dry bulb temperature in the drying zone was from 0° F. to +30° F. Several points may be noted from examination of this graph.

The drying period increases as the coating on the pattern is built up. This probably indicates that portions of the coating are re-wet and additional exposure is required to dry the increased volume of material. This also causes the temperature of the wet bulb equilibrium condition to be progressively lowered and to more closely approach the actual wet bulb temperature of the slurry vehicle.

The hump in the downward side of the cycle represents a short wet bulb equilibrium in the dip chamber during the drip operation which occurs before the pattern is taken into the drying chamber. The atmosphere in the dip chamber has a much higher dew point and vapor concentration; and, as the operation proceeds, the vapor concentration increases. This is reflected by the increasing temperature of the hump between the first and last dips.

The wet bulb equilibrium point is the flattened bottom portion of the curve. As soon as the pattern is dry, it is apparent that the surface temperature climbs rapidly toward the dry bulb temperature of the drying chamber. In accordance with the present process, however, the pattern is removed from the drying chamber at this point and immersed in the next dip bath.

In the unit illustrated herein, the patterns are provided with coatings of ceramic or refractory particles by wholly or partially immersing them in slurry dips. It is also contemplated that the slurry coatings could be applied to the patterns by a spray or an electrostatic spray or deposited by an electrotheosis process.

It will be apparent that part of the refrigerant may comprise various conventional liquefied gases, such as dimethyl ether or other gases mentioned in U.S. Patent No. 2,820,268; however, the refrigerant is preferably a non-combustible non-toxic material.

The frozen-mercury process is employed to make shell molds for investment casting of various metal parts for jet engines and rockets. Since the industry demands that such shell molds have a very high quality and be made to close tolerances, any process which produces inferior shell molds is commercially impractical. The process of this invention, however, is able to mass produce shell molds superior to those produced by the conventional process of the Kohl patents (i.e., U.S. Patent No. 2,820,-268) and to maintain a uniform high quality which cannot be maintained by the conventional Kohl process.

Thus, when making shell molds with 6 prime dip coats and 4 concrete dip coats, the process of this invention can consistently provide such molds with an overall weight which varies only a few ounces whereas the same type molds made by the Kohl process would vary in weight more than 1 or 2 pounds.

The molds made by the process of this invention are generally stronger, have a harder surface after firing, and have less tendency to flake, whereas molds made by the conventional Kohl process are generally inferior because of serious lamination problems and a tendency for the molds to flake. The process of this invention is, therefore, far superior to the Kohl process.

Unless the context shows otherwise, it will be understood that the term "parts" means parts by weight and that all percentages are by weight wherever mentioned in the specification and claims.

This application is a continuation-in-part of our copending application Serial No. 37,683, filed June 21, 1960, now abandoned.

Having described our invention, we claim:

1. In a process of forming shell molds from frozen mercury patterns, the steps, in a substantially enclosed system, of disposing the pattern in a dip chamber and dipping the pattern in a slurry mixture which is maintained at below −50° F. and comprises refractory materials, binder and a liquid vehicle to form a coating of said slurry mixture on said pattern, disposing said dipped mercury pattern in a drying chamber which has an atmosphere which has a dry-bulb temperature materially higher than the softening temperature of the mercury pattern and substantially above the boiling point of the slurry vehicle and which has a dew point below minus 50° F. until the vehicle has substantially evaporated therefrom and the temperature of said coating starts rising rapidly toward the dry-bulb temperature of the drying atmosphere, quickly removing said coated pattern from the drying chamber and dipping said coated pattern in a slurry mixture in a dip chamber, and repeating said process until a suitable number of layers of ceramic coatings have been built up on said pattern to form a shell mold, said pattern being maintained in the frozen condition throughout the process.

2. A process as defined in claim 1 wherein said drying chamber has an atmosphere with a dew point of about −60° F. to −80° F. and a dry bulb temperature of at least −10° F.

3. A process as defined in claim 1 wherein said liquid vehicle is monochlorodifluoromethane and said dry-bulb temperature is at least −10° F.

4. In a process of forming shell molds from frozen mercury patterns, the steps, in a substantially enclosed system, of disposing the mercury pattern in a dip chamber and dipping the pattern in a slurry mixture which is maintained at below −50° F. and comprises refractory materials, binder and a liquid vehicle to form a coating of said slurry mixture on said pattern, holding said coated pattern over the slurry mixture in the dip chamber to permit excess slurry to drip off of the coated pattern, disposing said coated pattern in a drying chamber having an atmosphere which has a dry bulb temperature materially higher than the softening temperature of the mercury pattern and substantially above the boiling point of the slurry vehicle and which has a dew point below minus 50° F. until the vehicle has substantially evaporated therefrom and the temperature of said coating starts rising rapidly toward the dry bulb temperature of the drying atmosphere, quickly removing said coated pattern from the drying chamber and dipping said coated pattern in a slurry mixture in a dip chamber, and repeating said process until a suitable number of layers of ceramic coatings have been built up on said pattern to form a shell mold.

5. The process of forming a ceramic shell mold from a frozen mercury pattern comprising the steps of removing surface moisture from the pattern, coating the mercury

pattern by dipping it into a refractory dip comprising a slurry of refractory materials, a binder, and a compatible refrigerant liquid maintained at a temperature below the softening point of the pattern, moving the coated pattern into a separate enclosed drying zone having an atmosphere with a dry bulb temperature that is materially higher than the boiling point of the refrigerant liquid and the softening temperature of the pattern and having a dew point sufficiently low to prevent the deposit of moisture on the coated pattern, as soon as the refrigerant liquid has been evaporated from the coating on the pattern, returning the coated pattern to a refractory dip maintained at a temperature below the softening point of the pattern, successively dipping and drying the coated pattern in like manner until a coating of the desired thickness is obtained, melting the mercury pattern, and firing the coating to convert the coating into a ceramic shell mold, the slurry of each refractory dip being maintained at a temperature below minus 50° F.

6. The process as defined in claim 5 wherein said refrigerant liquid is selected from the group consisting of monochlorodifluoromethane and dichlorodifluoromethane and said drying atmosphere has a dry bulb temperature of at least −10° F.

7. A process as defined in claim 5 wherein said liquid vehicle is monochlorodifluoromethane and said dry-bulb temperature is about −10° F. to +30° F.

8. The process of forming a ceramic shell mold from a frozen mercury pattern comprising the steps, in a substantially enclosed system of removing surface moisture from the pattern, coating the mercury pattern by dipping it into a refractory dip comprising a slurry of refractory materials, a binder, a compatible refrigerant liquid maintained at a temperature below the softening point of the pattern, moving the coated pattern into a drying atmosphere having a dry bulb temperature of about −10° F. to +30° F. and a dew point not in excess of about −50° F., as soon as the refrigerant liquid has been evaporated from the coating on the pattern, returning the coated pattern to a refractory dip maintained at a temperature below the softening point of the pattern, and successively dipping and drying the coated pattern in like manner until a coating of the desired thickness is obtained, the slurry of each refractory dip being maintained at a temperature below minus 50° F.

9. In a process of forming shell molds from frozen mercury patterns, the steps of disposing the mercury pattern in a dip chamber and dipping the pattern in a slurry mixture which is maintained at −50° F. to form a coating of said slurry mixture on said pattern, disposing said dipped pattern in a drying chamber which has an atmosphere with a dry bulb temperature substantially above the boiling point of the slurry vehicle and materially higher than the melting point of mercury and with a dew point of about −50° F. to −80° F. until the vehicle has substantially evaporated therefrom and the temperature of said coating starts rising rapidly toward the dry bulb temperature of the drying atmosphere, quickly removing said coated pattern from the drying chamber and dipping said coated pattern in a slurry mixture in a dip chamber, and repeating said process until a suitable number of layers of ceramic coatings have been built up on said pattern to form a shell mold, said pattern being maintained in the frozen condition throughout the process.

10. A process for forming ceramic shell molds on frozen mercury patterns in a thermally insulated enclosure containing an entry chamber, a series of dip baths having ceramic slurries therein, an exit chamber, means forming an intermediate chamber above each dip bath and a drying chamber above said intermediate chamber, said means including a retractable cover for closing off the drying chamber from the intermediate chamber, and retractable doors for closing off the drying chamber from said entry and exit chambers, said process comprising the steps of (1) forming a frozen mercury pattern, (2) conveying said pattern to said entry chamber and washing the pattern with a refrigerant, (3) moving the washed pattern into a first dip bath containing a ceramic slurry maintained at a temperature below −50° F., (4) elevating the pattern to the intermediate chamber and allowing surplus slurry to drip off of the coated pattern, (5) opening the retractable cover and moving the coated mercury pattern into a drying chamber, (6) closing said cover and providing the air in said drying chamber with a dew point below −50° F. and a dry bulb temperature of about −10° F. to +30° F., (7) as soon as the refrigerant liquid has been evaporated from the ceramic coating on the mercury pattern, moving the pattern back to the dip bath maintained at a temperature below −50° F., (8) repeating the cycle to apply many layers of ceramic material to the mercury pattern, thereby forming a shell mold on said pattern, (9) thereafter opening the door separating the drying chamber from the exit chamber, and (10) holding the pattern and shell mold in said exit zone for a substantial period of time while maintaining the temperature below −50° F.

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