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Nagell

[11] **3,755,915**

[45] **Sept. 4, 1973**

[54] **INVESTMENT CASTING SHELL MOLD DRYING AND DESICCANT REACTIVATION APPARATUS**

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[73] Assignee: **Nalco Chemical Company,** Chicago, Ill.

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[21] Appl. No.: **206,771**

[52] **U.S. Cl.** **34/95,** 34/71, 34/105, 164/26

[51] **Int. Cl.** **F26b 13/26**

[58] **Field of Search** 34/10, 26, 60, 71, 34/95, 105, 236; 164/25, 26

[56] **References Cited**

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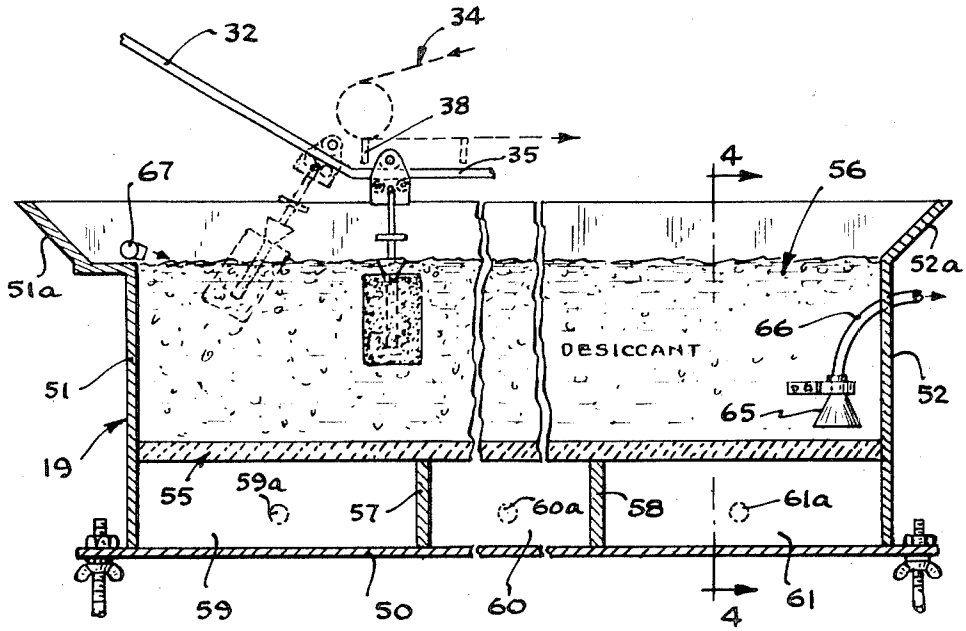
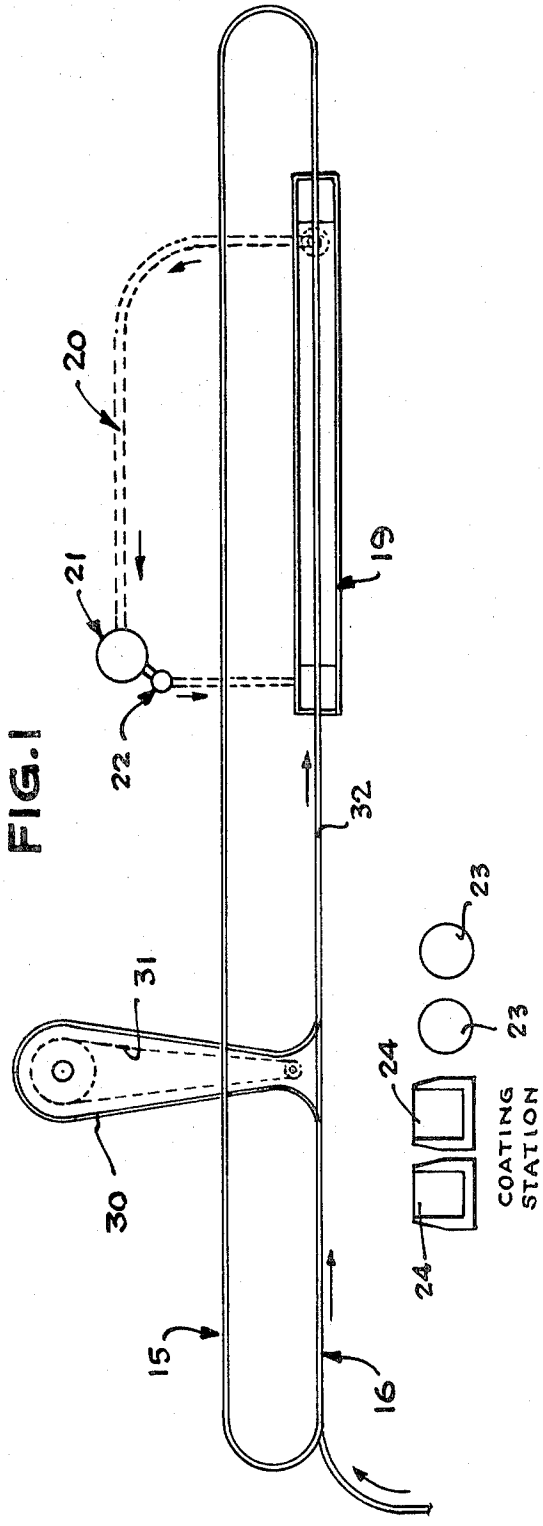
Assistant Examiner—James C. Yeung
Attorney—Lloyd L. Zickert et al.

[57] **ABSTRACT**

Drying slurry coatings on expendable patterns in making investment casting ceramic shell molds by moving the slurry coated patterns slowly through a fluidized bed of desiccant, and continuously reactivating the desiccant to provide an automated desiccant shell drying and desiccant reactivation process.

6 Claims, 11 Drawing Figures

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COATING STATION
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FIG. 1

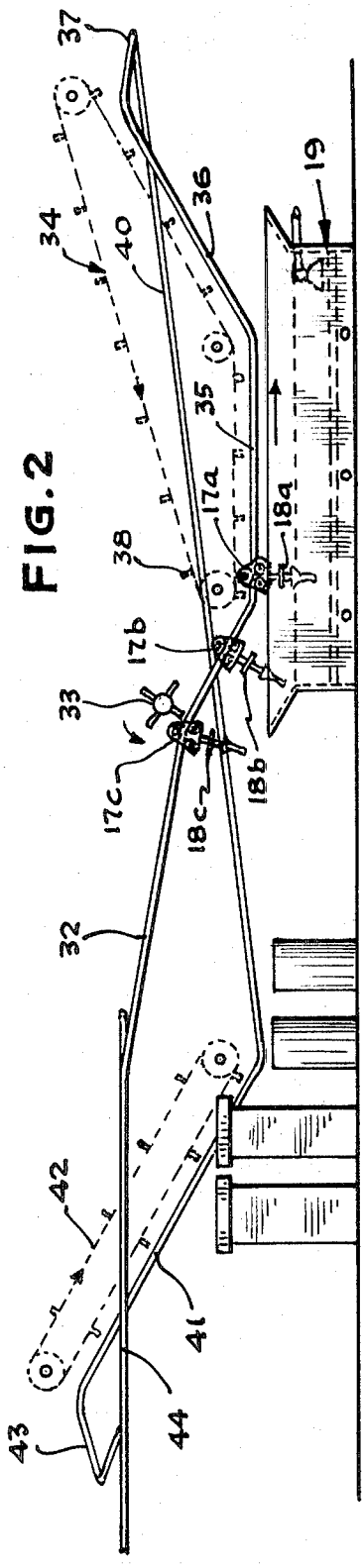
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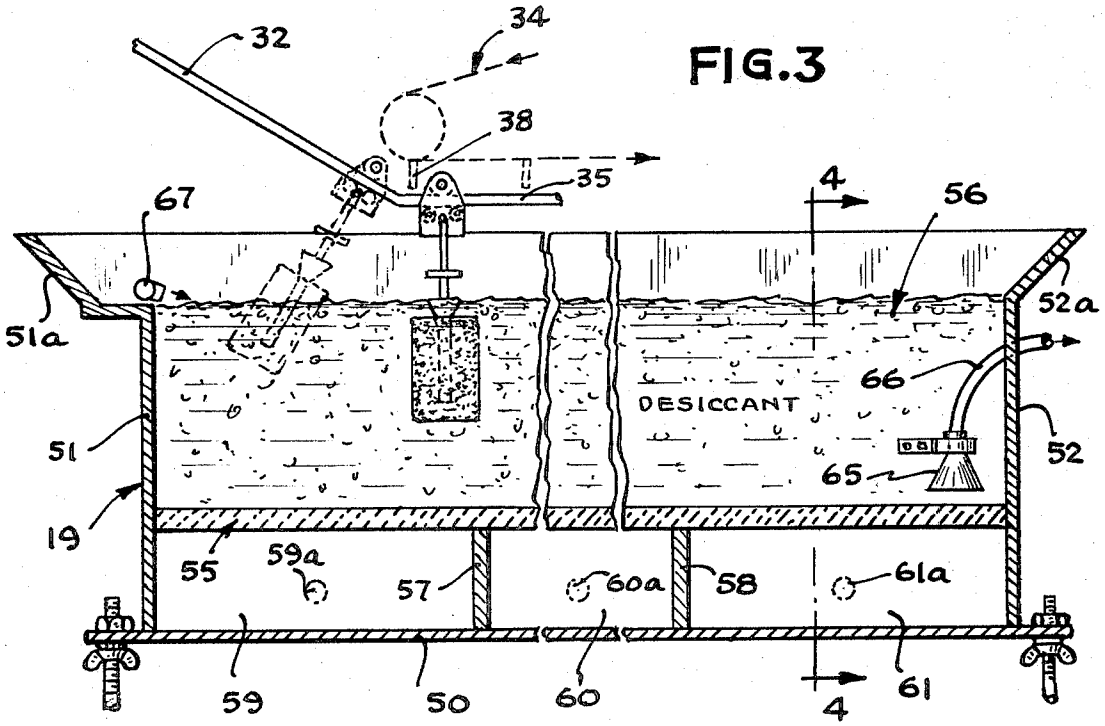
FIG. 2

FIG.3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DESICCANT
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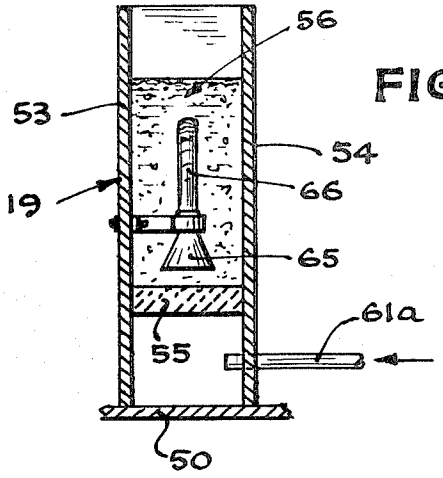
FIG.4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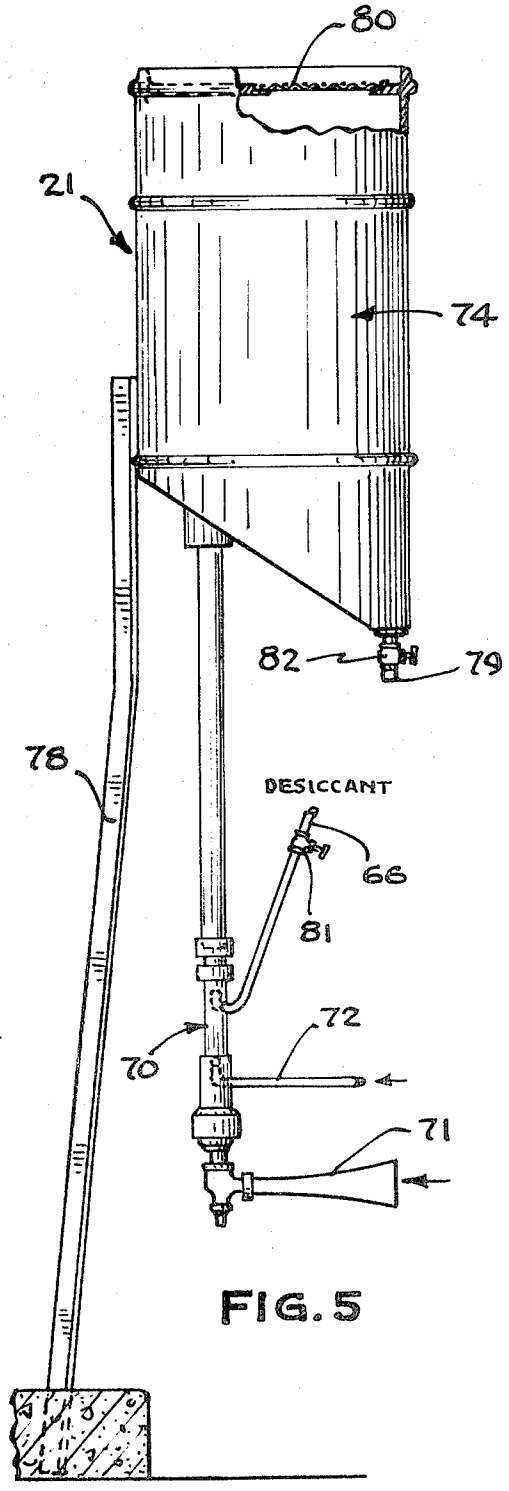


FIG. 5

FIG. 7

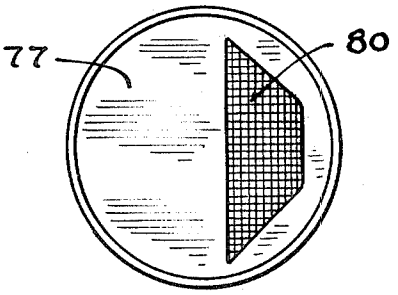
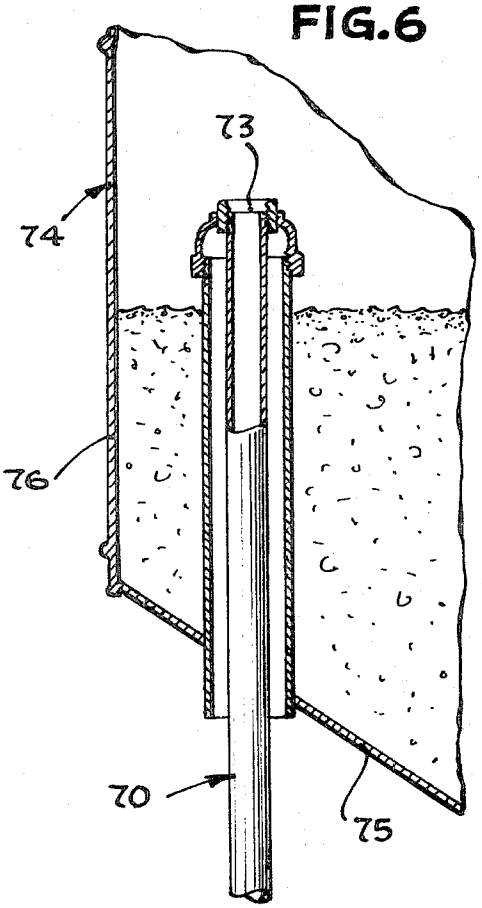


FIG. 6



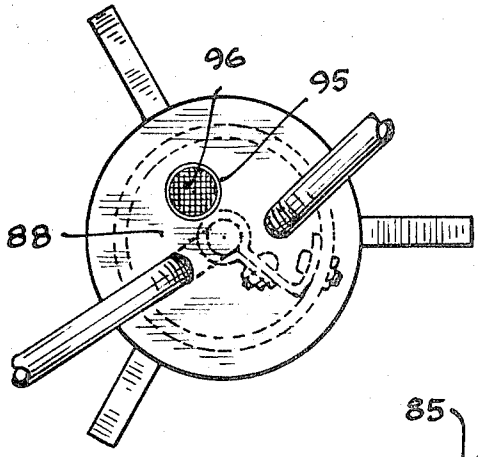


FIG. 9

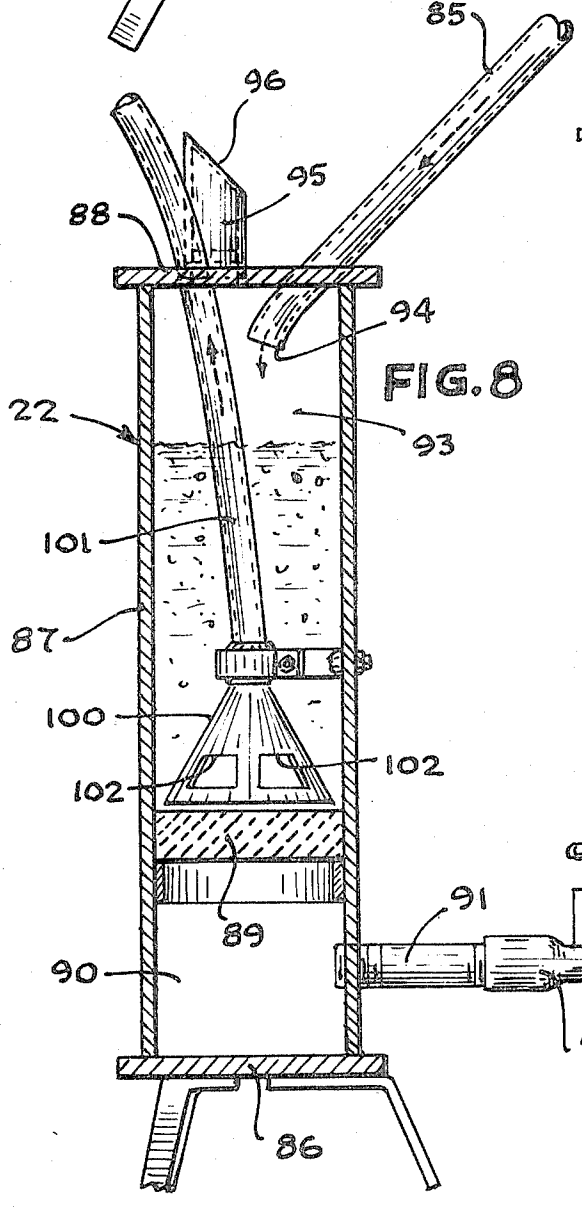


FIG. 8

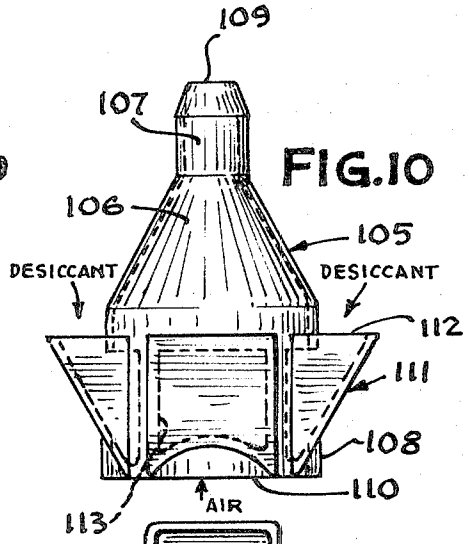


FIG. 10

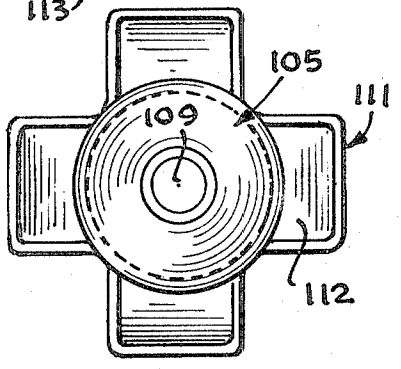


FIG. 11

INVESTMENT CASTING SHELL MOLD DRYING AND DESICCANT REACTIVATION APPARATUS

This invention relates in general to the making of ceramic shell molds used in the investment casting of metals, and, more particularly, to drying of slurry or slurry and stucco coats applied to an expendable pattern in the formation of a shell mold and, still more particularly, to shell drying in a fluidized bed of desiccant, together with continual reactivation of the desiccant.

Ceramic shell molds produced for the investment casting of metals are formed by successively coating and drying an expendable pattern, such as a pattern made of wax, plastic or other suitable material, where the coatings comprise slurry or slurry and stucco sand. For example, a slurry layer may include aqueous colloidal silica sol having suspended therein silica particles of −200 mesh, such as a granular fused silica, while the stucco material may include silica particles, such as granular fused silica of +100 mesh. In building up laminations on an expendable pattern, any number of layers of slurry and stucco material may be used in order to provide the desired characteristic for a shell mold, it being appreciated that a shell mold may be made up of one or more primary coats, together with one or more back-up coats and a final sealer coat. The silica particle size may vary in the primary and back-up coats in order to provide the desired structural characteristics. An example of some specific shell mold structures are disclosed in U. S. Pat. No. 2,948,032.

The problem dealt with by the present invention is the drying of the slurry coats, it being appreciated that each slurry coat with or without stucco material must be dried before a successive coat may be applied. Drying generally has been accomplished by allowing the coats to set up in a controlled atmosphere, where it would take on the average a day and a half to produce a shell mold having about six laminations.

It has been neretofore proposed to dry shell molds by immersing an expendable pattern with a coating to be dried into a fluidized bed of desiccant and then defluidizing the bed to implode the desiccant against the coating for a period of time and thereafter refluidizing the bed to withdraw the pattern. This method of drying requires considerable manual labor in handling the pattern and controlling fluidization of the desiccant, and drying efficiency decreases as the desiccant absorbs water.

The present invention concerns drying of shell mold coatings where expendable patterns with coatings to be dried are advanced by a conveyor into, through, and out of a fluidized bed of desiccant. The conveyor includes a monorail arranged in connection with a tank having a fluidized bed of desiccant and trolleys are provided on the monorail from which may be suspended expendable patterns. The expendable patterns are coated with slurry or slurry and stucco materials and then advanced along the monorail through the fluidized bed of desiccant and returned to the point where additional coatings of slurry or slurry and stucco may be applied for successful drying operations.

The desiccant in the fluidized bed absorbs water from the slurry layers on the expendable patterns to dry the layers, and is continuously being reactivated by removing desiccant from one end of the fluidized bed, reactivating the removed desiccant and returning desiccant in reactivated condition to the other end of the bed. In the reactivation process, heat is applied to the desiccant to remove absorbed water and then the desiccant is cooled before it is returned to the fluidized bed. Accordingly, the invention provides an automated shell drying and drying material reactivation method and apparatus which will reduce the overall drying time substantially in order to reduce the time needed to produce ceramic shell molds. Further, inasmuch as automated apparatus is provided, the cost of producing shell molds is similarly reduced by reduction of manual labor, and greater efficiency in shell drying is achieved.

It is therefore an object of this invention to provide a new and improved apparatus for producing ceramic shell molds used in the investment casting of metals.

Another object of this invention is in the provision of a new and improved method and apparatus for shell drying of ceramic shell molds which dries the molds in a fluidized desiccant bed and continually recirculates and reactivates the desiccant.

A further object of this invention is to provide a new apparatus for reactivating desiccant used in ceramic shell mold drying.

Other objects, features and advantages of the invention will be apparent from the following detailed disclosure, taken in conjunction with the accompanying sheets of drawings, wherein like reference numerals refer to like parts, in which:

FIG. 1 is a diagrammatic top plan view of an installation illustrating the present invention which includes a conveyor and an associated apparatus for drying ceramic shell molds by passing expendable patterns with coatings to be dried through a fluidized bed of desiccant, and apparatus for reactivating the desiccant;

FIG. 2 is a side elevational view of the apparatus of FIG. 1;

FIG. 3 is a greatly enlarged longitudinal sectional view taken through the fluidized bed desiccant drying tank and showing some parts in elevation for purposes of clarity;

FIG. 4 is a vertical transverse view taken along line 4—4 of FIG. 3;

FIG. 5 is an enlarged elevational view of the desiccant reactivator according to the invention showing some parts broken away for purposes of clarity;

FIG. 6 is a still further enlarged fragmentary detailed sectional view taken through the reactivator hopper and illustrating the discharge end of the reactivator tube;

FIG. 7 is a top plan view of the reactivator hopper;

FIG. 8 is a vertical sectional view taken through the cooling tower utilized in the reactivating loop;

FIG. 9 is a top plan view of the cooling tower;

FIG. 10 is a greatly enlarged elevational view of a modified funnel structure that may be utilized in the fluidized bed tank or the cooling tower for discharging desiccant from a fluidized bed; and

FIG. 11 is a top plan view of the funnel structure of FIG. 10.

Referring now to the drawings, and particularly to FIGS. 1 and 2, apparatus according to the invention for drying slurry and slurry and stucco coatings on expendable patterns in making ceramic shell molds, and reactivating the drying material or desiccant used for drying, is illustrated in one form where a conveyor 15 along which expendable patterns in the form of wax clusters or trees or the like may be advanced between coating and drying stations. The conveyor includes a

monorail or track **16** adapted to support any number of trolleys **17**, there being illustrated in FIG. **2** trolleys **17***a*, **17***b* and **17***c* where the trolleys support therefrom expendable patterns **18**. Along the monorail and therebelow a tank **19** containing fluidized desiccant provides the drying station wherein the coated expendable patterns are moved through the desiccant bed by a pusher which controls movement of the trolleys along the monorail track **16**. A closed desiccant reactivation loop **20** continuously takes desiccant from one end of the tank **19**, reactivates the desiccant in a reactivator **21**, cools the desiccant in a cooling tower **22**, then returns it to the desiccant tank in reactivated condition.

Along the monorail track **16** a coating station ahead of the drying tank **19** is provided which includes a pair of slurry pots **23** and a pair of stucco bins **24**. The slurry pots may include two different slurries such as where a primary and backup slurry arrangement is utilized for making up a shell mold. Similarly, the stucco bins would provide stucco sand of different sizes for use on primary and secondary layers. The stucco sand is fluidized in the stucco bins to facilitate the immersion and withdrawal of a pattern in the sand. It will be appreciated that an expendable pattern would first be immersed in the slurry of one of the pots and/or next immersed in the stucco sand of one of the bins, after which it would be subjected to a drying operation. The expendable patterns may be easily demounted from the trolleys and thereafter remounted during the coating operation. Prior to desiccant drying, an air set loop **30** having a power driven pusher member **31** may then be used only for the first and last coats of slurry on the expendable pattern. Thereafter the air set loop may be by-passed for successive coatings which may be directly desiccant dried.

As seen in FIG. **1**, the path of travel along the monorail track for the expendable patterns is counterclockwise. The trolleys having coated patterns to be dried are first advanced to a downwardly inclined section **32** of the monorail track where the trolleys advance by gravity to an indexing wheel **33**. The indexing wheel **33** will be operated in synchronism with an endless pusher **34** which sequentially advances the trolleys along a section **35** of monorail track directly mounted above the drying tank **19** and along an upwardly inclined section of track **36** to a turn-around section **37**. A plurality of equally spaced apart pusher members **38** are provided on the endless pusher **34** which maintain the trolleys in spaced relation along the track section **35** during the advancing of the coated expendable patterns through the drying tank **19**. Because the desiccant bed in the tank **19** is fluidized, it is self-leveling and presents negligible resistance to the patterns as they are moving through the bed. Accordingly, the power needed for driving the endless pusher **34** need not be too great and only sufficient to advance the trolleys and expendable patterns along the upwardly inclined section **36** of the track to the turn-around section **37**. The time period in which the patterns will be driven through the drying bed of desiccant depends upon the complexity of the pattern wherein the drying time may vary anywhere from 12 to 20 minutes but in any event would be long enough to effect the desired drying action on the coating. As already mentioned, the first slurry coat and the last slurry coat which would be a sealer are initially traversed through the air set loop **30**, while the intermediate coats need not be subjected to an air dry operation and may therefore go directly into the fluidized bed of desiccant. As seen in FIG. **2**, trolley **17***a* has just been picked up by a pusher on the pusher member **35**, while trolley **17***b* has been released by the indexer **33** to be caught by the next pusher on the pusher member, and trolley **17***c* is being held by the indexer until the pusher member is clear to accept the next trolley.

Following the drop-off of the trolleys and patterns at the turn-around track section **37**, the trolleys and patterns are returned to the opposite end of the conveyor by gravitational force which drives them along a downwardly inclined track section **40** to the base of an upwardly inclined track section **41** where an endless pusher member **42** suitably synchronized in movement relative to the endless pusher **34** drives the trolleys and patterns up the inclined section **41** to a second turn-around track section **43**. That brings the trolleys and patterns around to the horizontal inlet track section **44**, where they may dwell while the patterns may be removed for subsequent coating operations and thereafter advanced to the downwardly inclined track section **32** feeding to the desiccant drying tank or removed for other processing. Accordingly, the monorail track **16** of the conveyor **15** provides a continoous loop for movement of the trolleys and expendable patterns during the drying operation which essentially automates the drying operation of the slurry coats.

While the desiccant drying tank **19** may take any suitable form, it is preferably elongated, as illustrated, to provide an elongated fluidized bed of desiccant through which the expendable patterns with coatings to be dried may be advanced to effect the proper drying operation. As seen particularly in FIGS. **3** and **4**, the tank **19** includes a bottom wall **50**, opposite end walls **51** and **52** and opposite side walls **53** and **54**. The end walls **51** and **52** include at their upper ends flared wall sections **51***a* and **52***a* in order to provide clearance for the patterns as they enter and leave the bed of desiccant. Spaced upwardly from the bottom wall **50** on suitable supports is a defuser plate **55** upon which the desiccant bed **56** is supported and through which air is forced to effect the fluidizing of the desiccant. The defuser plate may take any suitable form wherein it is sufficiently porous to allow air to be forced therethrough and may, for example, be of the porous ceramic type which is commercially available. Partitions **57** and **58** arranged between the defuser plate **55** and the bottom wall **50** of the tank define air chambers **59**, **60** and **61**, having respectively air inlets **59***a*, **60***a* and **61***a*. Compressed air is delivered to the air chambers and forced upwardly through the defuser plate through the bed of desiccant **56** and out the upper surface of the bed, thereby fluidizing the desiccant. Any suitable desiccant may be used, such as a silica gel, preferably having a particle size of −20 +70 mesh. It is only necessary that the desiccant be of a type that will create a mechanical bond between water and the desiccant where subsequent application of heat will remove at least part of the water. The fluidized bed of desiccant is self-leveling and self-mixing by the air flow. The amount of compressed air delivered to the air chambers is such as to provide the desired fluidizing condition in the bed. It has not been heretofore known to dry shell molds by moving a coated expendable pattern continuously through a fluidized bed of desiccant.

In order to reactivate the desiccant as it absorbs water from the coatings on the expendable patterns,

the reactivator 21 and cooling tower 22 in the reactivation loop 20 continuously removes desiccant from one end of the tank and replenishes the desiccant in the other end of the tank. As shown in FIG. 3, desiccant is removed from the tank by mounting a funnel 65 in inverted position at the outlet end of the tank 19. The large end of the funnel is spaced slightly above the defuser plate 55 and the necked down end of the funnel is connected to a conduit 66 leading from the tank. Any suitable conduit may be used providing it is essentially smooth on its interior surface to reduce friction to the lowest possible amount. Desiccant, by being in the fluidized condition in the tank, will flow around the bottom end of the funnel 65 and part of the air moving up through the defuser plate will be trapped within the funnel, which will force desiccant through the funnel, the conduit 66, and to the reactivator 21 where the desiccant is reactivated. Reactivated desiccant is reintroduced into the tank 19 at the inlet end of the tank through an inlet nozzle 67 which may merely take the form of the open end of a piece of conduit.

The reactivator 21 includes a vertically arranged reactivator tube 70 into which desiccant to be reactivated is delivered through conduit 66 to a fitting arranged within the reactivator tube having its open end arranged substantially centrally within the tube and facing upwardly. At the lower end of the tube, heat in the form of hot gases is introduced through an inlet 71 by any suitable means. For example, the hot gases produced by a gas flame would be discharged into the inlet 71. It should be appreciated, however, that hot gases may be produced by any suitable means, and which will be introduced at the lower end of the reactivator tube 70. Between the point of heat introduction and desiccant introduction, compressed air is introduced into the tube through a compressed air line 72, which terminates within the reactivator tube in the form of a fitting arranged centrally within the tube and with an open end facing upwardly. The compressed air, at ambient temperature, mixes with and tempers the hot gases and then forces or draws the mixture upwardly in the tube, and which will then pick up desiccant as it is discharged from the desiccant inlet and remove water from the desiccant as it then travels upwardly through the tube to be discharged through the upper end 73 of the tube into a hopper 74 which collects the desiccant following reactivation in the reactivation tube. The hopper 74 is defined by an inclined bottom wall 75, an upstanding cylindrical wall 76 and a cover or top wall 77. The hopper and reactivation tube are suitably supported together and in upright position by a post 78 suitably anchored on the floor. The upper end of the reactivation tube 70 which extends within the hopper 74 is double-walled to inhibit the conducting of heat to the desiccant in the hopper.

As the desiccant is discharged from the reactivator tube 70 within the collecting hopper, it falls down onto the bottom wall 75 where, by gravity, it is then discharged through an outlet 79. In order to prevent a positive pressure from building up within the collection chamber, the cover 77 includes a fine mesh screen 80, closing an opening in the cover, allowing the pressure within the collection chamber to equalize with the atmosphere. Preferably, the screen is of about 80 mesh so that it will only allow fines to escape from the collecting hopper. The angle of the bottom wall 76 is dictated by the angle of repose of the desiccant and, for example, would be about 33° from horizontal for desiccant having a similar angle of repose. The movement of the mixture of compressed air and hot gases upwardly through the reactivation tube creates a slight negative pressure at the outlet end of the desiccant conduit 66 to assist in movement of desiccant within the conduit as it is taken from the tank 19.

The temperature of the hot gases from the heat source and the amount of compressed air at ambient preferably combines to provide a temperature at the desiccant exit of about 400° to 420° F. which is believed to be the most effective for removing water from the desiccant. The opening in the cover which gives the desired amount of action with respect to the proper movement of desiccant through the reactivation tube and into the collecting hopper 74. Movement of desiccant through the conduit 66 into the reactivation tube may be regulated by a valve 81 in the conduit. Similarly, the discharge of desiccant from the collecting hopper 74 may be regulated by a valve 82. It can also be appreciated that suitable instruments may be provided for controlling the compressed air supply and the heat supply so that the desired removal of absorbed water from the desiccant is accomplished by the reactivator 21.

From the reactivator 21 the desiccant is delivered through a conduit or pipe 85 to the cooling tower 22 which removes a sufficient amount of heat so that when the desiccant is returned to the fluidized bed it is about the same temperature as the desiccant already in the bed, which is mandatory in order to prevent improper drying of the slurry coats and improper heating of the expendable patterns. It should be appreciated that the expendable patterns and the coatings thereon are at about room temperature and therefore the desiccant into which they are immersed must also be at about room temperature.

The cooling tower 22 includes a bottom wall 86, an upstanding cylindrical side wall 87 and a top wall 88. Spaced upwardly from the bottom wall 86 is a defuser plate 89 which defines therebelow an air chamber 90. The defuser plate is of porous ceramic like the defuser plate in the desiccant tank 19, which permits fluidizing of the desiccant while it is in the cooling tower. A suitable source of compressed air is supplied to the air chamber 90 through a pipe 91 and a regulating valve 92. The conduit 85 which brings desiccant from the reactivator under gravitational force discharges the desiccant within the cooling tower into a cooling chamber 92. The desiccant is introduced into the cooling chamber from an inlet 94 at the upper end of the cooling chamber where it falls by gravitational force downwardly toward the defuser plate 89. The air within the air chamber 90 is forced upwardly through the defuser plate and through desiccant as it moves downwardly to the defuser plate. The air moves upwardly through the cooling chamber 93 and then out a standpipe 95 having its discharge end covered by fine mesh screen 96. This prevents a positive pressure from building up within the cooling chamber which would prevent desiccant from entering the cooling chamber through the inlet 94. The open end of the standpipe 95 is on an angle in order to increase the screen area. Like the screen used in the reactivator hopper, the screen is about 80 mesh size to prevent the desiccant from being accidentally discharged from the cooling tower.

Some of the air moving upwardly through the cooling tower is trapped in a funnel **100** arranged in inverted position on the defuser plate **89** with the large end resting on the plate and the necked down end connected to a discharge conduit or pipe **101** leading from the cooling tower and back to the desiccant drying tank **19** to the inlet nozzle **67.** A plurality of openings **102** are formed in the funnel **100** and through which desiccant gravitationally falls and enters the inside of the funnel **100.** Air trapped by the funnel forces the desiccant within the funnel upwardly out the cooling tower through the discharge conduit **101** and back to the desiccant drying tank. Thus, part of the air moving through the defuser plate becomes trapped in the funnel **100** and the other part of the air moves up and around the funnel to maintain the desiccant in the cooling tower in fluidized condition. The fluidizing air being at ambient will therefore cool the desiccant as it moves downwardly through the cooling tower to be discharged therefrom back to the drying tank. The heat absorbed by the air is then removed from the cooling tower through the standpipe **95.**

The temperature of the desiccant incoming to the cooling tower would be about 120°F. and the outgoing desiccant temperature would be about ambient.

It should be appreciated that other types of desiccant reactivators and other types of cooling towers than those illustrated in the drawings could be utilized to recirculate reactivated desiccant in the drying tank. Further, the reactivator and cooling tower assembly could be remotely located from the ceramic shell mold building area so as to remove the heat generated by the reactivator from the shell building area. This would permit the maintaining of a more constant temperature in the shell building area in order to eliminate any adverse effect on the shells or expendable patterns. Preferably the compressed air used by the drying tank, the reactivator, and the cooling tower is taken from a single manifold and thereafter volume regulated as needed.

Another form of funnel structure that may be utilized for removing desiccant from a fluidized bed is illustrated in FIGS. **10** and **11,** it being appreciated that the funnel shown in these Figs. and generally designated by the numeral **105** could be utilized in the desiccant drying tank or in the cooling tower. The funnel **105** includes a conical wall **106** having the large end facing downwardly and the small end facing upwardly, a cylindrical necked down wall **107** at the upper end of the conical wall, and a cylindrical wall **108** extending downwardly from the lower larger conical wall. The necked down wall **107** defines at its upper end an outlet **109** which may be connected to a conduit for delivering desiccant to another station. The lower end of the cylindrical wall **108** is open to define an air inlet **110** into which air is introduced to force desiccant upwardly through the conical wall **106** and to the outlet **109.** A plurality of upwardly opening scoops **111** are formed along the lower cylindrical wall **108** which have inlet openings **112** facing outwardly that receive desiccant from the bed, and outlet openings **113** through which desiccant is discharged into and within the cylindrical wall **108** and into the air stream. Thus, the funnel **105** illustrates another funnel structure that may be used to remove desiccant from a fluidized bed.

It will be understood that modifications and variations may be effected without departing from the scope of the novel concepts of the present invention, but it is understood that this application is to be limited only by the scope of the appended claims.

I claim:

1. Apparatus for desiccant drying investment casting shell molds and reactivating the desiccant comprising, an elongated drying tank containing a fluidized bed of desiccant, conveyor means for supporting and transporting expendable patterns dipped in slurry or slurry and stucco through the desiccant bed, and means continuously taking desiccant from the bed, reactivating the desiccant, and returning it to the bed.

2. Apparatus as defined in claim **1,** wherein said last-named means includes a reactivator for receiving desiccant from the bed and applying heat to remove water therefrom, and a cooling tower for receiving desiccant from the reactivator and cooling same before returning it to the bed.

3. Apparatus as defined in claim **2,** wherein said last named means includes a funnel-shaped member and conduit for taking desiccant from the tank, said tank including a defuser plate for supporting the desiccant and means forcing air upwardly therethrough, said funnel-shaped member including a large open end facing the defuser plate and in slightly spaced relation therefrom to define an opening with the plate through which desiccant passes to a point below the funnel, and a necked end connected to the conduit, wherein the funnel traps air to drive desiccant through the conduit.

4. Apparatus as defined in claim **3,** wherein the reactivator includes an elongated upstanding tube terminating in an upper open end, a hot gases inlet at the lower end of the tube, means producing and driving hot gases into said hot gases inlet, a desiccant inlet in the tube spaced upwardly from the hot gases inlet, a compressed air inlet in the tube spaced intermediate the hot gases inlet and the desiccant inlet, a hopper defining a collecting chamber mounted on the upper end of the tube so the upper open end is arranged within said chamber, a cover on said hopper having a screened opening, a bottom wall in the hopper supporting regenerated desiccant, said bottom wall being at an angle, and a discharge opening for the hopper at the lower end of the bottom wall to permit gravitational discharge of desiccant.

5. Apparatus as defined in claim **4,** wherein the cooling tower includes an upstanding body having a desiccant receiving chamber and an air chamber separated by a defuser plate upon which is supported a bed of desiccant, an inlet to the desiccant chamber connected to the reactivator, means for supplying compressed air to the air chamber to force air upward through the plate, a funnel in said desiccant chamber having a large open end resting on the defuser plate and an opposing necked end connected to conduit leading from the tower, openings in said funnel through which desiccant falls to the inside of the funnel, and a screened opening in the upper end of the tower to permit communication between the desiccant chamber and atmosphere, wherein the compressed air fluidizes and cools the desiccant in the desiccant chamber and forces desiccant within the funnel through the conduit.

6. Apparatus as defined in claim **5,** wherein said conveyor means includes a continuous track for transporting the expendable patterns with coatings between coating and drying stations.

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