Dec. 6, 1949 R. E. BARR 2,490,193

METHOD OF MOLDING

Filed Aug. 15, 1947 2 Sheets-Sheet 1

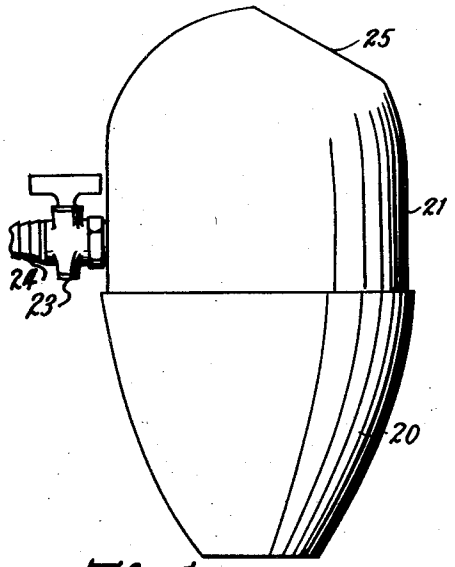

Fig. 1

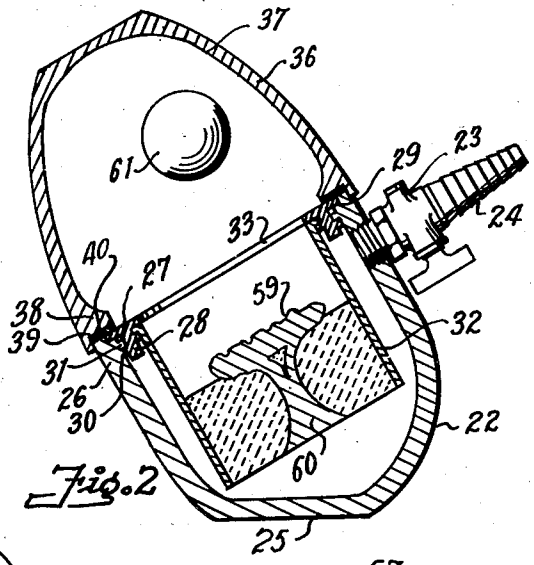

Fig. 2

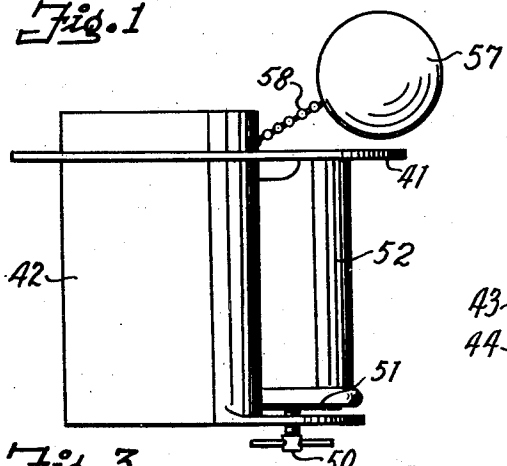

Fig. 3

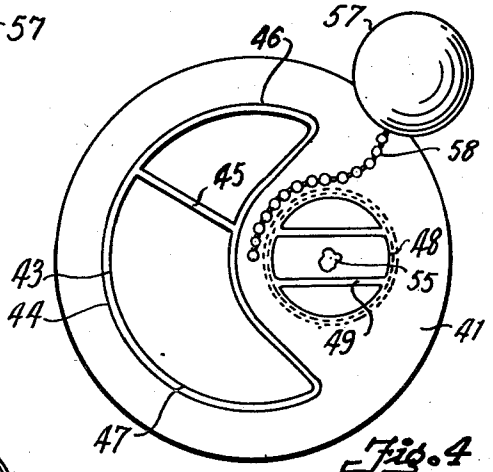

Fig. 4

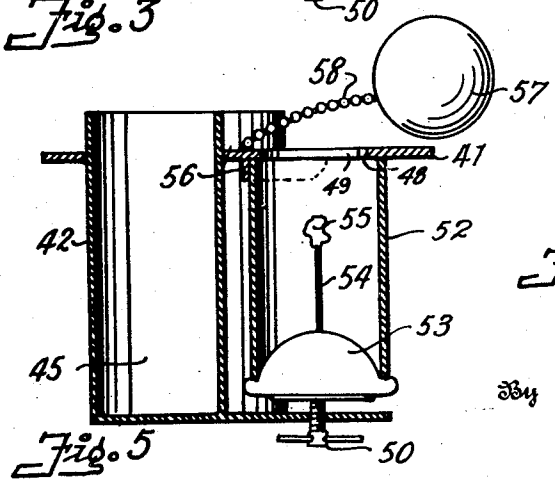

Fig. 5

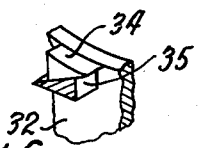

Fig. 6

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METHOD OF MOLDING

Filed Aug. 15, 1947 2 Sheets-Sheet 2

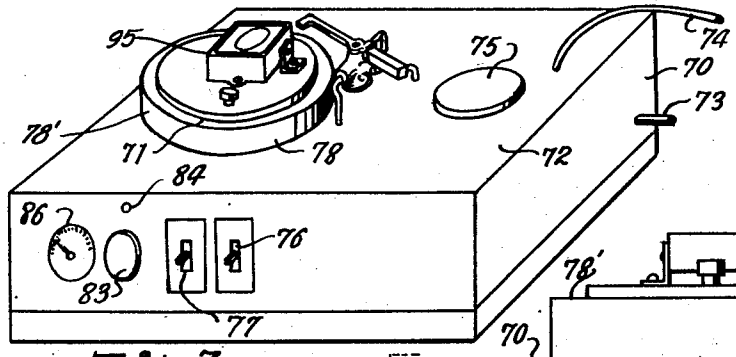

Fig. 7

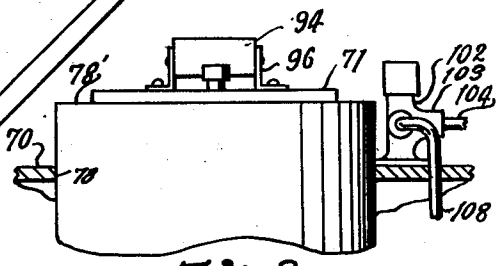

Fig. 8

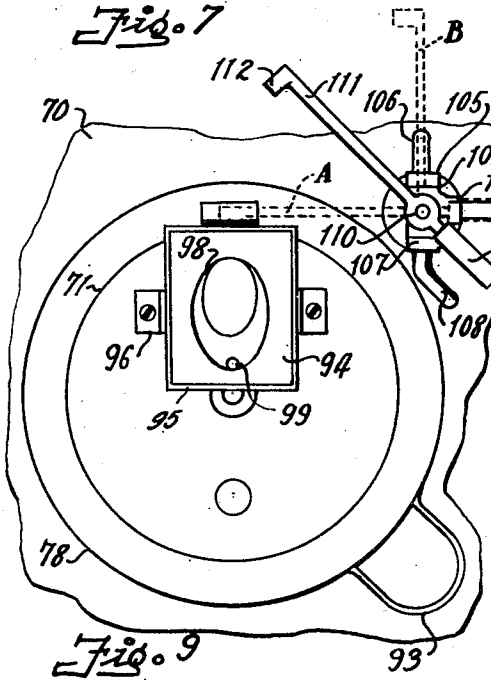

Fig. 9

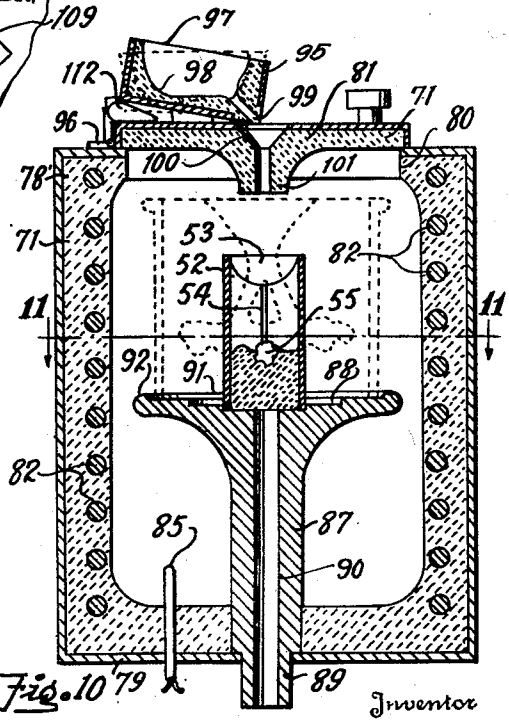

Fig. 10

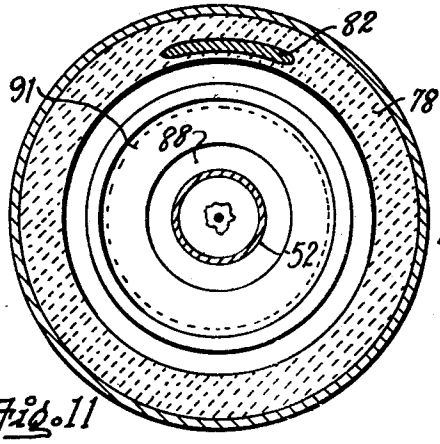

Fig. 11

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METHOD OF MOLDING

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Application August 15, 1947, Serial No. 768,874

11 Claims. (Cl. 22—193)

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This invention relates to new and useful improvements in methods of molding, and in particular extremely accurate casting of articles of very close dimensions and tolerances.

Although the invention is applicable in a great number of instances such as the forming of items of jewelry or portions of precision instruments and other similar devices, it is particularly applicable to the casting of dental inlays and certain types of dental restorative castings. For the purposes of clarity the invention will be described largely with respect to use in the dental profession. However, it is to be noted that the invention is not limited to such use, but may be advantageously applied in a number of entirely dissimilar arts.

The problems of accurate and satisfactory casting of small and extremely accurately dimensioned elements are substantially the same in all instances in which such casting necessarily is employed whether the same be a filling for a tooth or an item of jewelry or an important element of precision instrument. Therefore, it is further to be noted that the various problems and obstacles to accurate casting which will be set out hereinafter with regard to casting applications in the dental field, exist in other arts or applications where accurate casting is desirable, and that the method and means contemplated by this invention finds equal advantages and applicability to all such instances where accurate casting is desired as well as with particular respect to the formation of various dental devices or prosthetic elements.

In casting procedures, the existence of a master form or pattern is necessary and for the purposes of this application may be assumed to be in existence. For instance, in the utilization of this invention for the formation of a dental device, such as an inlay, the existence of a model or pattern may be assumed. Such a model normally consists of a wax form or pattern of the size and shape of the article to be cast and amounting to an exact duplicate of such article. Although such impressions are normally formed of wax, the invention is obviously applicable with the utilization of patterns or models formed of other materials. The customary procedure is to form or obtain such a pattern or model through usual and well-known procedures, and then to duplicate such pattern or model in gold or gold alloy, or other suitable material or alloy, such as is customarily employed for the constitution of such devices. This invention deals particularly with such duplication.

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In the past, in duplicating of a wax form or pattern for the creation of a gold inlay for instance, it has been customary to mount the pattern upon a suitable sprue-forming wire and to paint or coat the pattern carefully with a creamy mixture of an investment compound, similar in nature to plaster of Paris. Great care has been necessary in such a coating operation to prevent the occlusion of air bubbles between the investment compound and the wax pattern since such bubbles will obviously cause imperfections in the article cast from the mold which is eventually produced around the pattern. Following this painting or coating operation, the wax pattern is suitably positioned within the usual casting ring, and the latter filled with an investment compound mixture which is allowed to harden around the pattern and the investment compound previously applied to said pattern or form. In this manner, a plaster-like mold is formed around the pattern. This mold, after removal of the wax therefrom, may be employed for the casting of a duplicate of the wax pattern in metal or other suitable material.

After the mold so formed has hardened, it is customarily heated to cause the melting or burning of the wax impression therefrom whereby a cavity in the shape of the desired article remains within said mold with a passage created by the sprue-forming wire leading from the exterior of the mold to said cavity. Following this step, the normal procedure is to remove the mold from the place of heating and to fill or cast the same with molten metal or other suitable material. Several methods have been developed for forcing the molten molding material into the cavity within the mold, two of the principal methods being centrifugal casting and casting under air or water vapor pressure. All of these methods necessitate the removal of the mold from the place of heating so that the mold undergoes considerable cooling during the casting operation. Later, after the molten casting material has solidified, the mold may be broken up or dissolved so that the finished cast article is obtained.

A considerable number of problems and disadvantages arise in the course of forming a suitable cast article with this herebefore employed method. To begin with, a considerable degree of skill is required to paint or coat the wax pattern properly with the creamy investment mixture. Quite often, air bubbles are trapped between the investment mixture and the wax pattern regardless of the care and skill displayed by the technician. Also, the investment mixture it-

self, which consists of a plaster-like material mixed with water, contains large numbers of gaseous bubbles which are not always obvious to the eye but which cause imperfections in the mold produced and consequently in the article cast therein. These gaseous bubbles may be formed of air or other gaseous materials which were originally present in the water or trapped in the investment powder or which were generated or freed in some manner by the mixture of the investment powder with the water.

Methods have been developed for partially avoiding this problem, such methods involving the placing of the investment mixture, after it has been stirred or spatulated to the proper consistency, under vacuum conditions so as to exhaust gaseous bubbles therefrom. However, the actual investing of the wax pattern with the investment mixture is carried out in open air with ample opportunity for aeration or the occlusion of bubbles during such procedure. These methods also contemplate the evacuating of the investment compound after it has been poured into the casting ring around the pattern. Obviously, evacuating the investment compound at any point is of some advantage. However, the removal of anything but relatively large bubbles from points adjacent the surfaces of the investment compound either before pouring or after its introduction into the casting ring, is questionable.

Another difficulty lies in controlling the expansion of the casting ring and the investment compound after the wax impression has been burned from the finished mold. At present, it is necessary to remove the mold from a relatively hot furnace which may be in the neighborhood of 800° F. to 1350° F., and to allow the mold to stand in the open air while the casting is being poured. Obviously, a considerable opportunity occurs for distortion of the mold by contraction as the latter cools when following such a method. In addition, it is sometimes difficult to regulate certain of the centrifugal casting devices in accordance with the individual conditions, such as mass and solidifying time, which vary considerably in accordance with the particular object being formed within the mold. The air pressure or water vapor pressure methods of casting involve very definite risks of such air or water vapor being trapped within the mold cavity and causing an imperfect casting. For this reason, the positioning of the wax pattern within the casting ring is very critical and must be very carefully determined to reduce the likelihood of obtaining undesirable results. Obviously, in the various steps through which the impression and the mold must be carried, a number of opportunities arise for displacement or malpositioning of the impression within the mold.

It is, therefore, one object of this invention to provide an improved method for forming casting molds wherein the investment compound mixture is evacuated before, during, and/or after mixing, and while the same is being introduced or poured into a form around the article which is to be duplicated.

An important object of the invention is to provide an improved method whereby the component parts of an investment compound mixture may be evacuated before mixture, then thoroughly admixed and spatulated while under partial high vacuum, and subsequently introduced into a casting form while being maintained under partial high vacuum so as to preclude the presence of any gaseous bubbles or voids in the completed mold.

Yet another object of the invention is to provide an improved casting method in which the molten metal or other material is drawn into the mold while the latter is being subjected to a partial high vacuum.

An important object of the invention is to provide an improved method for casting wherein the mold is held at the desired elevated temperature during the casting process and at the same time a partial vacuum applied thereto to draw the molten metal or other material into the mold cavity and to insure the evacuation of any gaseous bubbles within the cast product and prevent the formation of any voids therein, thereby greatly improving the texture of the metal or material being cast.

A still further object of the invention is to provide a casting furnace having provision for melting metal or other material from which the cast article is to be formed and for substantially simultaneously introducing said molten material into a mold within the furnace while at the same time applying a partial high vacuum thereto.

Yet another object of the invention is to provide an improved molding device having provision for receiving the component parts of a molding compound while retaining the same in separation and placing the same under partial high vacuum, and having means for admixing and thoroughly spatulating and combining said ingredients without an interruption of the vacuum being applied thereto; and wherein, in addition, the device may include means for pouring the molding mixture so compounded into a suitable form in the shape desired for casting, while maintaining the vacuum pull upon the mixture without interruption.

A pertinent object of the invention is to provide an improved method for producing very accurate castings having intricate shapes and very close dimensions or tolerances, and which are substantially exact and absolute duplicates of the original pattern or form which it is desired to copy.

A construction designed to carry out the invention will be hereinafter described together with other features of the invention.

The invention will be more readily understood from a reading of the following specification and by reference to the accompanying drawing, wherein an example of a means for carrying out the method of the invention is shown, and wherein:

Fig. 1 is a side elevation of a molding device constructed in accordance with this invention,

Fig. 2 is a vertical, sectional view of the device shown in Fig. 1, with the same being upended,

Fig. 3 is a side elevation of an alternate insert for the molding device,

Fig. 4 is a plan view of the insert shown in Fig. 3,

Fig. 5 is a vertical, sectional view of the insert shown in Fig. 3,

Fig. 6 is a fragmentary, enlarged, isometric view of the locking lugs which secure the casting ring shown in Fig. 2 to the retaining collar,

Fig. 7 is an isometric view of a casting device constructed in accordance with this invention,

Fig. 8 is an enlarged, fragmentary, side elevation of the upper end of the casting furnace,

Fig. 9 is an enlarged, plan view of the furnace portion of the casting device,

Fig. 10 is an enlarged, vertical, sectional view of the casting furnace, and

Fig. 11 is a horizontal cross-sectional view taken on the line 11—11 of Fig. 10.

In the drawings, the numeral 20 designates a molding device or receptacle following the teaching of this invention. The device includes an upper molding container or shell 21 having a general hemi-ovoid shape or outline. The shell 21 is hollow, having a molding chamber 22 therein, and carries a suitable valve or petcock 23 extending laterally from one side wall near the lower edge thereof. The pet cock 23 is provided with the usual type of nozzle or hose fitting 24 to which a suitable rubber hose (to be described hereinafter) may be attached. The upper and opposite wall of the shell is flattened to form a rest or support 25 upon which the shell 21 may be disposed. As will be noted from Fig. 2 of the drawings, when the shell is placed upon the rest 25, its longitudinal axis extends upwardly at an angle of between 30° and 40°.

The open lower end of the shell 21, as viewed in Fig. 1, carries an annular seating surface 26 in which an annular, internal shoulder 27 is machined or otherwise formed for receiving a locking collar 28. The collar 28 is of such diameter as to enter into the open end of the chamber 22 and carries a peripheral external flange 29 having a snug fit within the seating face 26 so as to rest upon the shoulder 27. The collar 28 has an outside diameter somewhat less than the inside diameter of the shell 22 and carries a plurality of radially extending wedge-like lugs 30 upon its outer surface spaced below the flange 29. The lugs 30 engage beneath similar lugs 31 which project radially inwardly from the inner wall of the shell 21 at a point slightly below the shoulder 27. Thus, by rotating the collar 28, the lugs 30 and 31 engage and coact to lock the collar in position within the shell 21 by urging the flange 29 into snug engagement with the shoulder 27.

A cylindrical, open-ended, casting ring 32, of the usual construction, is carried within the collar 28. An annular flange 33 projects inwardly from the upper end of the collar so as to abut the upper end of the ring 32, and lugs 34 and 35, similar to the lugs 30 and 31, and carried by the ring 32 and the collar 28, respectively, are adapted to engage one another, so that upon rotation, the ring 32 is urged into snug engagement with the underside of the flange 33 and thus securely positioned within the shell 21. Obviously, the various sets of lugs may be arranged in any desired fashion, or other suitable means may be employed for securing the casting ring in position within the molding chamber 22. In addition, provision may be made, if desired, for alining the ring within the chamber in any one particular position which may appear desirable, such as causing any particular portion of the ring to always be adjacent the higher or lower side of the chamber 22, as viewed in Fig. 2 of the drawings.

A mixing or spatulating cup 36 forms the lower portion of the molding device as viewed in Fig. 1. The cup 36 has the general outline of an ellipsoid cut along its minor axis, although any suitable or desirable shape or configuration may be employed for this cup. The cup is hollow and contains a mixing chamber 37 of conical or hemi-ellipsoid shape in which the ingredients of the molding compound are mixed and spatulated. The side wall of the cup 36 is thickened at 38 around the upper edge of the cup as viewed in Fig. 1. A seating groove 39 is formed in the edge of the cup and carries a suitable packing ring or gasket 40. The seating face or edge 26 of the shell 21 is adapted to enter the groove 39 and seat against the packing ring 40. It will be noted

that the width of the groove and the ring is sufficient to allow the same to overlap or overlie the outer edge of the flange 29 of the collar 28. Thus, a supplemental retaining action is obtained for securing the collar 28 in position. It is not essential that the joint between said collar and the shell 21 be sealed, but only the joint between the cup 36 and said shell.

The casting ring 32 is relatively large in diameter and is adapted for the formation of molds for relatively large castings, such as large or intermediate partial dental restorations when this device is employed for the formation of dental devices. A somewhat smaller casting ring is provided in the supplemental, and preferred, insert which is illustrated in Figs. 3—5 of the drawings, the latter insert also providing for utilization of additional desirable features of the method contemplated by this invention.

This supplemental insert includes a circular, disk-like spider or diaphragm 41 of such thickness and diameter as to permit seating upon the shoulder 27 of the shell 21 and engagement by the edge of the mixing cup 36. A crescent shaped container 42 having an open top 43 and a closed bottom 44 extends through the diaphragm 41 so as to have its open upper end projecting a short distance thereabove while its closed bottom is positioned a considerable distance below said diaphragm. The dimensions of the container 42 are such as will permit its insertion into the chamber 22 when the diaphragm is seated upon the shoulder 27. An offset, vertical partition 45 divides the container 42 into a small or water-containing chamber 46 and a large or investment compound-containing chamber 47.

As will be noted in Fig. 4 of the drawings, the container 42 is offset with respect to the center of the diaphragm 41, and a circular opening 48 is provided in the opposite half of the diaphragm more or less adjacent or contiguous to the curved inner wall of said container. The opening 48 is traversed by a plurality of bars 49 which may be formed integrally of the diaphragm 41 or consist of suitable elements secured thereto so as to overlie said opening. This, to prevent sealing or closure of the opening during the pouring operation by mixing ball 57.

The bottom 44 of the chamber 42 is extended laterally so as to underlie the opening 48. A suitable wing bolt 50 is threaded through the extended portion of the bottom 44 and extends vertically in vertical alinement with the center of the opening 48. A follower disk 51 is carried by the upper end of the bolt 50 above the extended portion of the bottom 44, said disk being adapted to be moved upwardly and downwardly by means of the bolt 50.

The usual small casting ring 52, comprising an open-ended cylinder as is customarily employed for casting dental inlays and other similar small articles, is positioned between the underside of the diaphragm 41 and the upper side of the disk 51. The opening 48 is slightly less in diameter than the casting ring 52 so that the latter does not pass therethrough, although the bars 49 may be used for such retaining purpose if so desired. As is customary, the open lower end of the ring 52 is closed by the usual sprue-former in the shape of a hemispherical plug or cap formed of rubber or some other suitable material. A sprue-former wire 54 extends axially upwardly of the casting ring from the sprue-former 53 and carries upon its upper end the model or pattern 55 which it is desired to

duplicate. Normally, in the dental profession, this will consist of a wax pattern of the cavity to be filled or a wax model of the item it is desired to duplicate in a casting. Obviously, by tightening of the wing bolt 58, the casting ring along with the sprue-former are urged upwardly into snug engagement with the underside of the diaphragm 41 and held securely in such position. To aid in positioning the casting ring beneath the diaphragm, a short depending skirt 56 may be provided about the opening 48 on the underside of said diaphragm and extending annularly in close relation to the edge of said opening. For spatulating purposes, a ball 57, formed preferably of some relatively heavy and corrosion resisting material such as brass or bronze, is secured by a chain 58 to the central portion of the diaphragm 41, the chain being attached to the upper side of said diaphragm and being of such length as to allow the ball 57 a considerable degree of movement within the mixing chamber 37 when this latter described insert is positioned within the molding chamber 22 and the molding device is assembled.

For the purposes of clarity and conciseness, the means employed to carry out the method involved in this invention has been described prior to such method so that the latter may be recited with the benefit of a specific application. However, the method involved remains the dominant feature while the particular device described represents only one means for carrying out such method.

In the utilization of this device and, at the same time following the subject method, the pattern 55 is positioned within the casting ring 52 in the usual manner and the ring is mounted within the insert device shown in Fig. 3 of the drawings. Measured quantities of water and investment compounds are placed in the chambers 46 and 47 and the insert structure introduced into the chamber 22 with the diaphragm 41 resting upon the shoulder 27. The shell 21 may be held in a semi-vertical or vertical position during such procedure with its open end directed upwardly so that the investment ingredients remain at rest within the container 42. The ball 57 may be rested upon the diaphragm 41, and the mixing cup 36 placed in position by engaging the groove 39 over the seating face 26 of said shell. A suitable source of vacuum, such as a vacuum pump (not shown) capable of producing a high vacuum or partial high vacuum is then attached through a flexible conductor to the nozzle 24 of the pet cock 23. The pet cock is opened and the vacuum pump is started.

Once any reasonable degree of vacuum is established within the molding device, the atmospheric pressure exerted upon the outer surfaces of the shell 21 and the cup 36 is sufficient to hold the same in engagement, the packing ring 40 serving to prevent the entry of air between said elements into the interior of the device. It is pointed out that in neither of the modifications described is there any sealing between the mixing chamber 37 and the molding chamber 22, so that the vacuum exerted through the pet cock 23 is communicated to both chambers.

It is preferable, although not necessary, that the device remain in the aforementioned position for a short period after the vacuum within the device has been created. It is well known that nearly all water contains a considerable proportion of gas, both dissolved and otherwise held, and it is desirable to eliminate such gas before the mixing procedure is instituted. At the same time, air and other gases trapped in the dry investment compound powder are also evacuated and removed. After a suitable period of such evacuation, the device is inverted into the position shown in Fig. 1 of the drawings. This inversion causes the ingredients of the investment compound to fall into the mixing chamber 37 along with the ball 57. The device may then be shaken and agitated, causing the ball 57 to move about rapidly within the mixing chamber in the manner of a spatulator or a pestle to mix and combine the water and the dry investment compound into a smooth, homogeneous, thoroughly-stirred investment mixture. It will be noted, the application of vacuum is continued during this mixing process so that any gas which may be evolved or released is immediately removed. Because of the agitation of the mixture, different portions of the ingredients are constantly being brought to the surface for evacuation of any gas which may be entrapped.

The mixing is continued for a suitable time, or until the technician is certain that a smooth, uniform mixture has been obtained. The molding device is then again inverted and placed in the position shown in Fig. 2 of the drawings. When the large casting ring 32 is employed, it is of no particular consequence how the collar 28 is positioned with respect to the pet cook 23. However, when using the smaller ring 52, it is desirable that the diaphragm 41 be so rested upon the shoulder 27 as to place the opening 48 in diametric opposition to the pet cock 23. It is also desirable with both sizes of rings that in passing from the position of the molding device shown in Fig. 1 to the position shown in Fig. 2, that the device be turned in a clockwise direction so that the investment mixture will flow down the left hand side of the cup 36, as viewed in Fig. 2, into contact with the diaphragm 41 and through the opening 48 into the casting ring 52. The upstanding portion of the side wall of the container 42 which projects above the diaphragm acts as a baffle to prevent the investment mixture from being rapped or collected within said container.

The molding device is now transferred to a suitable vibratory table of the usual and ordinary type, and rested thereon upon the flattened face 25 whereby the device is supported at an angle as shown in Fig. 2. In this position, the major portion of the investment mixture overlies the opening 48 and may pass downwardly therethrough into the casting ring 52. The vibrating step causes the investment mixtures to pack tightly around the pattern 55 and insures the obtaining of a satisfactory and accurate reproduction of said pattern in the investment. Again it is to be noted that the application of vacuum is continued through the mixing, the pouring, and the vibrating steps. Thus, at all times the mixture is protected against contact or exposure to the atmosphere so that gaseous bubbles cannot be trapped within the finished mold and thus cause imperfections of the cast object.

After a suitable vibration period atmospheric pressure may be allowed to enter the molding device by opening pet cock 23 thereby breaking the vacuum seal, and the mixing cup 36 removed from engagement with the molding shell 21. Since the casting ring 52 is filled with a compacted fluid mass, there is no tendency for air to re-enter the investment mixture, and in any event such re-entry would only be into a relatively thin portion adjacent the exposed upper surface of said mixture immediately below the

opening 48. As a supplemental compacting force, the inrushing air serves to compact further the investment compound around the wax pattern in the ring. The casting ring is now removed and allowed to stand until the investment mixture has set to the desired degree, after which the casting procedure may be continued.

Substantially the same method may be followed in making molds for larger castings by employing the large size casting ring 32. A relatively large pattern or wax impression 59 with suitable sprue-formers 60, consisting of wax rods or other material, is positioned within the lower portion of the casting ring 32 and the latter filled with an open-air mixed investment mixture to a point immediately below the critical portions of the pattern. In this manner, the lower end of the casting ring is closed to permit additional pouring operations in the upper portion thereof. The ring is then locked into position within the collar 28 and the latter locked in position within the open end of the shell 21. Now, the proper proportions of the investment mixture ingredients including water and investment compound are placed in the mixing chamber 37 and spatulated or mixed therein in the open air. After a smooth open air mixture is obtained a mixing ball 61 is dropped in this mixture, the shell 21 is inverted over the mixing cup and placed thereon as shown in Fig. 1 of the drawings. While vacuum is being established, as described hereinbefore, the device is shaken and agitated to aid in removal of gaseous bubbles from the investment mixture before the latter is introduced into the casting ring. It is desired that the suitable loose ball 61, similar to the ball 57, be placed in the cup 36 to aid in agitating and further blending the investment mixture before introduction into the ring 32. Some suitable means may be employed for preventing the ball 61 from entering the ring 32 as by providing a spider (not shown) over the open upper end of the ring 32, or by attaching the ball to the cup 36 by a suitable length of small chain (not shown).

After the investment mixture has been thoroughly mixed and properly evacuated, the molding device is inverted to allow said mixture to flow downwardly into the casting ring and thereby form a mold of the pattern 59. The molding device is vibrated in the same manner as before and substantially the same procedure followed throughout after said inversion of the molding device. The shell 21 may be supported upon the flattened base 25, as shown in Fig. 2, or may be suitably held in an upright position during the vibration and subsequent operation depending upon the nature and size of the pattern 59. Obviously, in many instances it will be preferable if not essential that the molding shell be supported in a substantially upright position to insure proper filling of the casting ring 32. Following the vibration step, the casting ring 32 is removed and allowed to stand in the same manner as the ring 52 until the investment mixture has hardened to a proper degree therein.

Having thus formed an extremely accurate mold of the pattern or wax impression which it is desired to reproduce, it is necessary that the wax or other material of which the pattern is formed be removed from said mold. A number of procedures exist for such removal, the most widely used being heating of the molding in a suitable furnace until a major portion of the wax or other material has melted and run from the molding, with the remainder of such material being burned from the molding and passing therefrom as products of combustion or volatilization. The temperatures employed for such burning off operations normally run from about 800° F. to 1350° F. In Figs. 7–11 of the drawings, a suitable device is shown for carrying out the burning off operation as well as the subsequent casting procedure.

This device icludes a rectangular housing or cabinet 70 of sufficient depth to accommodate a furnace or oven 71 set into its upper surface 72, and of sufficient length and breadth as to provide a small working surface upon said upper surface. A conductor 73 for connection to a suitable vacuum pump (not shown) extends through one end wall of the housing or cabinet and is connected to a suitable distribution valve as will be described hereinafter. A suitable flexible conductor 74 for connection with the nozzle 24 of the molding device 20 extends through the upper wall or top of the cabinet 70 and has its inner end also connected to the distributor valve for the selective application of vacuum therethrough to said molding device. The usual vibratory device (not shown) is disposed within the interior of the cabinet 70 and has its vibratory table 75 extending upwardly through the top 72 of said cabinet and projecting a slight distance thereabove. This table may be employed for the vibrating step described hereinbefore with respect to the molding procedure. An electrical switch 76 may be mounted in the front of the cabinet 70 for operation of the vacuum pump, and a similar switch 77 provided for actuation of the vibratory device.

The furnace or oven 71 is positioned near one end of the cabinet 70, being set down in the cabinet so as to have a major portion of its body contained within the interior of the cabinet while only the upper portion of the furnace projects thereabove through a circular opening 78 cut in the top 72. Obviously, the entire furnace may be positioned above the top 72 of the cabinet, if so desired. Although a cylindrical electrical furnace is described, any shape or style of furnace may be employed. An electrical furnace has been found particularly adaptable by reason of the ease of temperature control.

The furnace 71 includes an insulated cylindrical housing 78' having a closed bottom 79 and the usual open top 80 closed by a hinged, insulated lid 81. Any suitable type of electrical heating elements 82 are embedded in the walls of the furnace and connected through an adjustment rheostat 83 and a pilot light 84 to a source of electrical power (not shown). A thermocouple 85 projects into the interior of the furnace and is connected to a pyrometer instrument 86 for indicating the furnace temperature. The rheostat 83, the pilot light 84, and the instrument 86, may all be mounted in the front wall of the cabinet 70, if so desired.

A heavy walled conductor 87 extends through the bottom 79 and upwardly within the furnace to a point adjacent the medial portion of said furnace. A circular vacuum table 88 is carried upon the upper end of the conductor 87, while a suitable connection nipple 89, formed integrally with the conductor 87, extends below the bottom of the furnace. A passage 90 extends through the nipple 89 and the conductor 87 to the central portion of the table 88. The table is provided with a pair of concentric circular stepped surfaces 91 and 92 upon its upper side, the inner surface 91 being of such diameter as to receive one end of the smaller casting ring 52, while the

outer surface 92 is of such diameter as to receive one end of the large casting ring 32. Thus, either size of casting ring may be supported upon the table 88 and accurately centered with respect to the furnace, it being pointed out that the table is spaced a sufficient distance below the upper end of the furnace as to allow the complete reception of the large-sized casting ring within said furnace. Obviously, means may be provided on the table 88 to receive a variety of casting rings of different shapes and sizes.

This furnace is suitable for burning out the wax patterns from the mold produced as previously described, such operation preferably being carried out with the hinged lid 81 in an open position. However, the burning out procedure may be carried out elsewhere and the furnace 71 employed only for the purposes of preheating the mold and maintaining it at a molding temperature during the subsequent operations. Such an extraneous burning out device would be the small auxiliary warming or heating chamber 93 secured to one side wall of the furnace 71 as shown in Fig. 9 of the drawings.

A small melting crucible 94 is carried within a rectangular, open top box 95 pivotally mounted upon a pair of brackets 96 upon the upper side of the lid 81. The pivotal mounting of the crucible allows the same to undergo a limited degree of movement in a vertical plane as shown in dotted lines in Fig. 10 of the drawings. The cup 97 of the crucible has a pocket or recess 98 near one end in which the material which is to form the casting is melted. In the dotted line position shown in Fig. 10, the pocket 98 comprises the lowest portion of the crucible so that molten material collects therein. The opposite, higher end of the crucible cup communicates with a spout 99 extending downwardly at an angle to the underside of said crucible. The crucible is so positioned upon the brackets 96 as to place the outlet end of the spout 99 in vertical alinement with a conical recess 100 formed in the center of the lid 81. A reduced spout 101 extends downwardly from the recess 100 and projects into the interior of the furnace. In this manner, with the crucible in the dotted line position, as shown in Fig. 10, metal or other material may be melted within the pocket 98, and then the crucible may be pivoted upon the brackets 96, or tilted into the full line position shown in Fig. 10, to cause the molten metal to flow through the spout 99, the recess 100 and the spout 101 into the mold or casting ring positioned below the latter spout upon the table 88. With this method, it is not necessary to remove the mold from the furnace in which it has been heated before introducing the molten metal thereinto, and the casting operation is performed within the oven allowing the casting ring to remain continuously in an oven atmosphere to which the delicate investing compound has become accustomed. Therefore, the undesirable effects of cooling and shrinkage of the mold when the latter is exposed to the open air as in centrifugal and other casting methods are avoided. Also, the inter-oven casting method set forth herein reduces the oxidation of the metal being cast thereby improving the texture of the metal in the completed casting.

For the purpose of drawing the molten metal into the cavity of the mold, the passage 90 is connected to the vacuum pump by the connection of a suitable conductor to the nipple 89. In this manner, a suction or vacuum pull is created which draws the molten metal downwardly through the opening caused by the sprue-former wire 54, or the sprue-former 60, into the cavity which represents the outline of the article to be cast. The advantages of employing such a vacuum to completely fill the mold cannot be over estimated. It is to be noted that such vacuum or mold filling force may be exerted concurrently with the heating of the mold within the furnace and that the exerting of this force may be continued for as long a period of time as necessary or desirable. The apparent mass of the molten metal is not increased in this method such as occurs in centrifugal casting so that distortion or cracking of the mold is avoided. At the same time, the disadvantages of air or water vapor pressure casting are avoided in that air or other gases are removed from the mold by reason of the vacuum so that such air or water vapor cannot be trapped in the mold cavity and cause an imperfect casting. The investment compound normally used for such casting procedures has a certain degree of porosity. It is therefore possible for air to be drawn through the mold and to create a partial vacuum within the interior of said mold and especially in the cavity thereof. As the molten metal flows into the sump formed in the upper end of the mold by the sprue-former 53, or 60, said metal acts to impede the passage of air from the interior of the furnace into the body of the mold. Therefore, a quite considerable vacuum may exist within the interior of the mold, said vacuum acting to remove any gases or vapors present and at the same time to draw the molten metal downwardly into the mold cavity and into intimate contact with all the contours and convolutions thereof. Actual experience has shown that this casting procedure produces castings having an extremely high degree of accuracy and faithfulness of reproduction with little or none of the problems and disadvantages inherent in other methods being encountered.

After the casting pour has been made, the casting ring may be allowed to remain within the furnace 71, until complete solidification of the molten metal has taken place and for such time thereafter as is desirable for heat treatment of the casting so formed. The mold may then be removed and the investment material suitably disintegrated to free the finished casting. With particular respect to dental work, a casting so produced has usually been found to require little or no additional finishing other than brushing and trimming off the sprue necessarily connected to the cast article.

For the purpose of minimizing the degree of technical skill required in controlling the tilting of the crucible 94 and the application of vacuum to the passage 90, a three-way valve 102 is positioned upon the upper surface 72 of the cabinet 70 contiguous to the periphery of the furnace 71. The valve 102 may be of any suitable or desirable construction and is preferably of the type having three branches, one of which may be selectively connected to either of the other two. The principal branch 103 of the valve is connected through a suitable conductor 104 to the vacuum supply conduit 73. One lateral branch of the valve 105 is connected through a similar conductor 106 with the nipple 89 leading to the passage 90, while the opposite branch 107 of the valve is connected through a suitable conductor 108 with the flexible conductor 74 which extends

upwardly through the top 72 of the cabinet 70. A control handle 109 is connected to the stem 110 of the valve for regulating the position of the latter, and an elongate arm 111 is formed integrally with said handle so as to move therewith as the handle is swung to the various valve positions. As will be noted in Fig. 9 of the drawings, the valve 102 is positioned near the rearward portion of the furnace 71 and to one side thereof, and the arm 111 is of such length that its outer end may be swung to a position adjacent the rearward side of the crucible 94. A wedge member 112 is formed upon the outer end of the arm 111 and is adapted to engage beneath the crucible when the handle 109 of the valve is swung to the dotted line position A shown in Fig. 9. As appears in Fig. 10 of the drawings, the wedge member 112 by engaging beneath the rearward edge of the crucible 94, tilts the latter so as to cause the molten metal contained therein to flow into the casting ring contained within the furnace. In this position of the valve, the conductor 106 is placed in communication with the conductor 104 so that a vacuum is applied directly from the vacuum pump (not shown), the conductor 73, the conductor 104, the valve 102, the conductor 106, and the passage 90 to the underside of the mold within the casting ring which has been positioned in the furnace 71. Thus, the one operation of moving the valve to the dotted line position A causes a vacuum to be applied to the mold in the furnace, and at substantially the same time tilts the crucible so as to cause the molten metal within the latter to flow into said mold. Obviously, other expedients may be employed to accomplish this same result although the present structure has proven to be extremely effective while simple and inexpensive to manufacture.

In order to place a suction or apply a vacuum to the flexible conductor 74 for any desired purpose, such as application of vacuum to the molding device 20 described hereinbefore, the handle 109 may be swung through 90° to the dotted line position B shown in Fig. 9 of the drawings, in which position the conductor 104 is placed in communication with the conductor 108, the latter being connected directly to the flexible conductor 74. Thus, only one valve need be employed in order to apply vacuum at either of the two desired points. Of course, when the handle is in the full line position shown in Fig. 9 of the drawings, both conductors 106 and 108 are shut off from communication with the conductor 104 so that vacuum is applied to neither and in effect, the vacuum is entirely closed off. Again obviously, a separate valve may be employed for applying vacuum to the furnace 71 with an additional valve or valves being employed to communicate such vacuum to the conductor 74 or to shut off said vacuum entirely.

In the particular illustration shown in the drawings, a suitable casting metal such as gold or gold alloy, or other casting alloys may be melted within the crucible 94 by the application of heat from a suitable burner or blow torch which may operate on any one of a number of gaseous fuels. The employment of such burners for melting the casting material is well known and need not be described. However, it is to be noted that various melting methods may be employed, such as induction heating of the material by electrical means or by the application of an electric current directly to the casting material for the purposes of melting the same. The crucible may be arranged for tilting to close an electrical circuit for melting purposes, the reverse tilting of the crucible causing said circuit to be broken after melting is had and at the same time allow the molten metal to flow into the furnace while initiating the application of vacuum to said furnace.

The benefits and advantages obtained by following the complete method herein set out are manifold. A number of these advantages have been discussed hereinbefore and result in a more accurate and desirable product as well as the elimination of a number of objections to previously employed casting methods and devices. In addition, an important advantage is realized in that the degree of skill of a technician in employing this method and means may be somewhat less than that normally required by other methods or devices. Substantially all of the casting operations are reduced to mere mechanical routine steps so that a relatively unskilled person may quickly and easily be trained to produce very accurate castings of extreme high quality so that long training periods and high degrees of requirements of skill, both of a manual nature and pertaining to technique, are eliminated.

The foregoing description of the invention is explanatory thereof and various changes in the size, shape and materials, as well as in the details of the illustrated construction may be made, within the scope of the appended claims, without departing from the spirit of the invention.

What I claim and desire to secure by Letters Patent is:

1. The method of producing a mold of an article which includes subjecting the ingredients of a molding compound to a partial vacuum while maintaining said ingredients separated from one another, admixing the ingredients in the presence of a partial vacuum to provide a molding compound, and forming the compound around the article.

2. The method of producing a mold of an article which includes, subjecting the ingredients of a molding compound to a partial vacuum while maintaining said ingredients separated from one another, subsequently admixing the ingredients in the presence of a partial vacuum to provide a molding compound, forming the compound around the article in the presence of a partial vacuum, and vibrating the molding compound into place around the article in the presence of a partial vacuum.

3. The method of producing a mold of an article which includes, placing a thin coating of a molding compound upon the articles, positioning the article in a form, subjecting the ingredients of a molding compound to a partial vacuum while maintaining said ingredients separated from one another, admixing the ingredients in the presence of a partial vacuum to provide a molding compound, and forming the compound around the coated article in the presence of a partial vacuum.

4. The method of producing a mold of an article which includes, subjecting the ingredients of a molding compound to a partial vacuum while maintaining said ingredients separated from one another, admixing the ingredients in the presence of a partial vacuum to provide a molding compound, and forming the compound around the article in the presence of a partial vacuum.

5. The method of producing a mold of an article which includes, subjecting the ingredients of

a molding compound to a partial vacuum while maintaining said ingredients separated from one another, admixing the ingredients in the presence of a partial vacuum to provide a molding compound, forming the compound around the article in the presence of a partial vacuum, and vibrating the molding compound into place around the article in the presence of a partial vacuum.

6. The method of producing a mold of an article which includes, subjecting the ingredients of a molding compound to a partial vacuum while maintaining said ingredients separated from one another, admixing the ingredients in the presence of a partial vacuum to provide a molding compound, forming the compound around the article in the presence of a partial vacuum, and removing the article from the mold.

7. The method of producing a mold of an article which includes, subjecting the ingredients of a molding compound to a partial vacuum while maintaining said ingredients separated from one another, admixing the ingredients in the presence of a partial vacuum to provide a molding compound, forming the compound around the article in the presence of a partial vacuum, and heating the mold to remove the article therefrom.

8. The method of producing a mold of an article which includes, subjecting the ingredients of a molding compound to a partial vacuum while maintaining said ingredients separated from one another, admixing the ingredients in the presence of a partial vacuum to provide a molding compound, forming the compound around the article in the presence of a partial vacuum, and heating the mold to remove the article therefrom and to expand the mold.

9. The method of producing a mold of an article which includes, subjecting the ingredients of a molding compound to a partial vacuum, while maintaining said ingredients separated from one another, admixing the ingredients in the presence of a partial vacuum to provide a molding compound, forming the compound around the article in the presence of a partial vacuum, vibrating the molding compound into place around the article in the presence of a partial vacuum, allowing the molding compound to set at least partially, removing the article therefrom, and heating the mold to expand the same.

10. The method of producing a mold of a pattern entirely within the confines of a small, substantially sealed chamber, containing the pattern in one portion thereof, which includes first depositing the ingredients of a molding compound within a second portion of said chamber, sealing said chamber and applying constantly partial vacuum to said chamber during all the herein recited steps to first remove air particles from the chamber and from the ingredients before said ingredients are mixed, then intimately admixing the ingredients in said second portion of the chamber while maintaining said partial vacuum and then at least partially inverting said chamber to flow and form the mixed compound around the pattern while continuing the application of said partial vacuum to said chamber.

11. The method set forth in claim 10 further characterized by the step of vibrating the molding compound into place around the article within said chamber and in the presence and continuance of said partial vacuum.

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