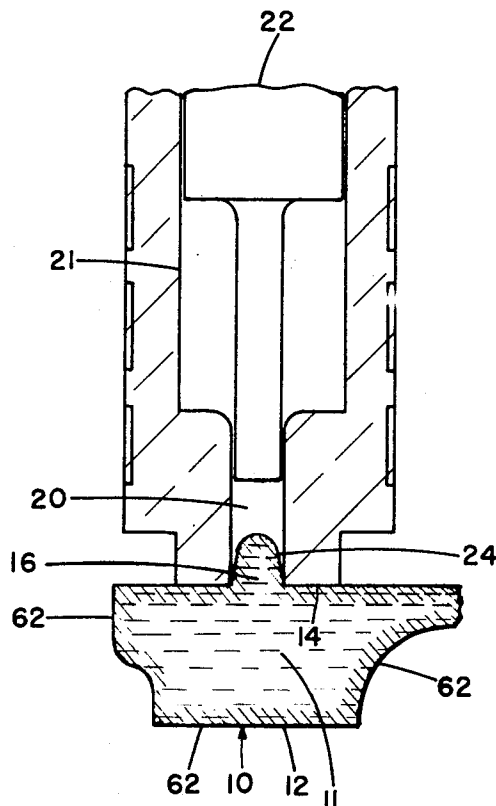


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6 Claims, 5 Drawing Figures



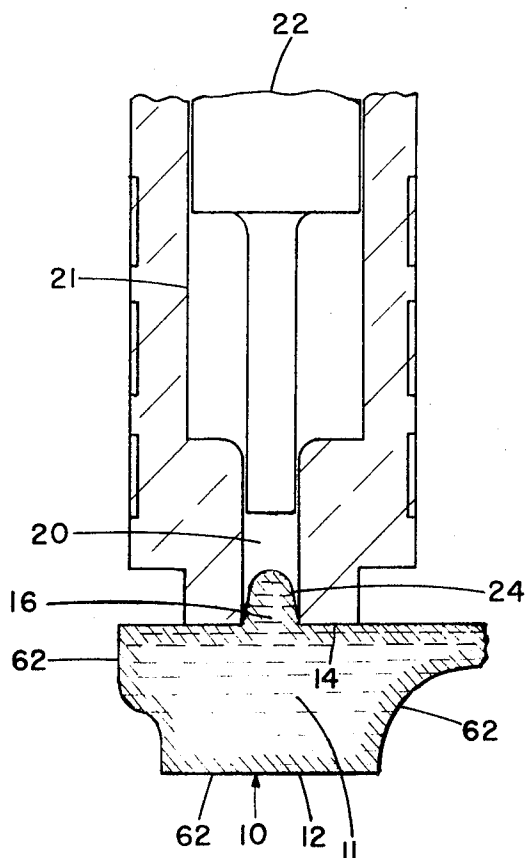


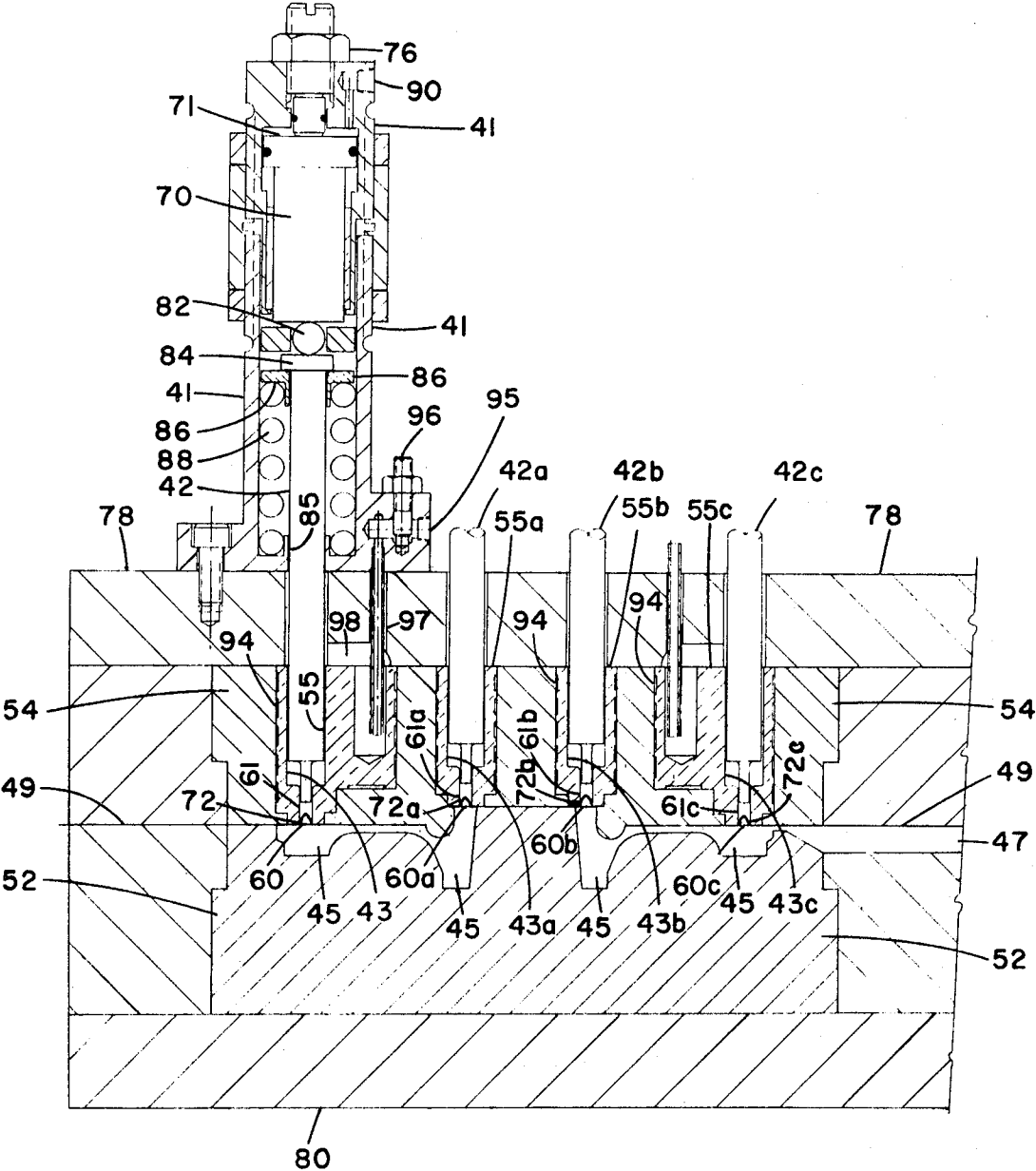
FIGURE 1a

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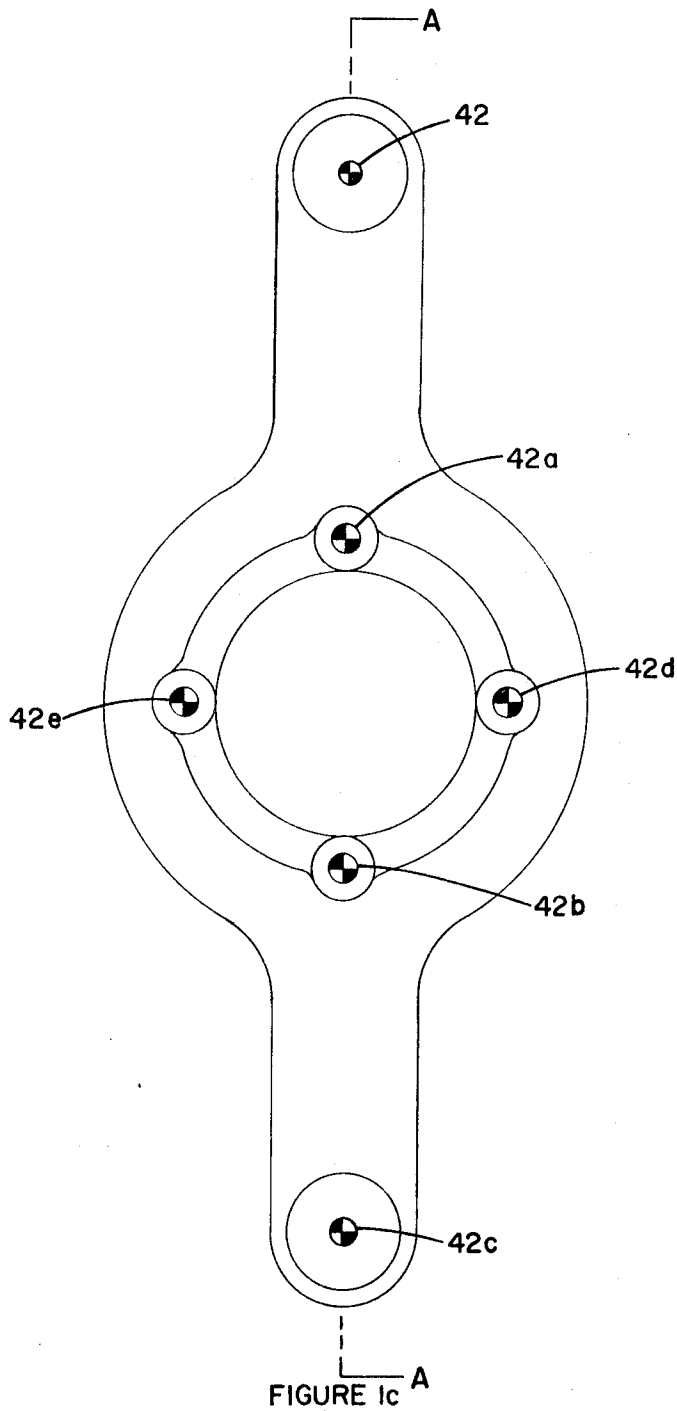
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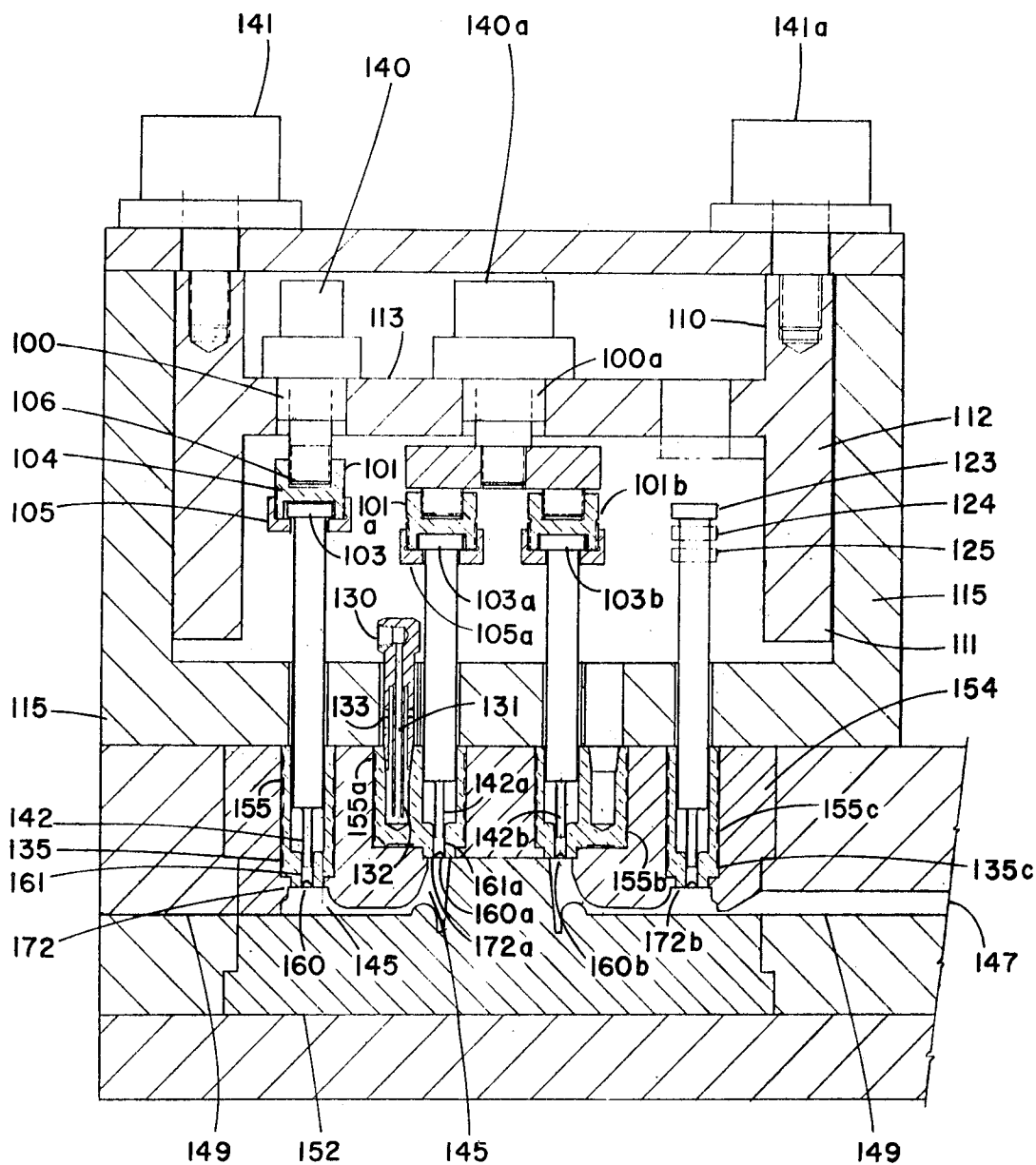


FIGURE 2

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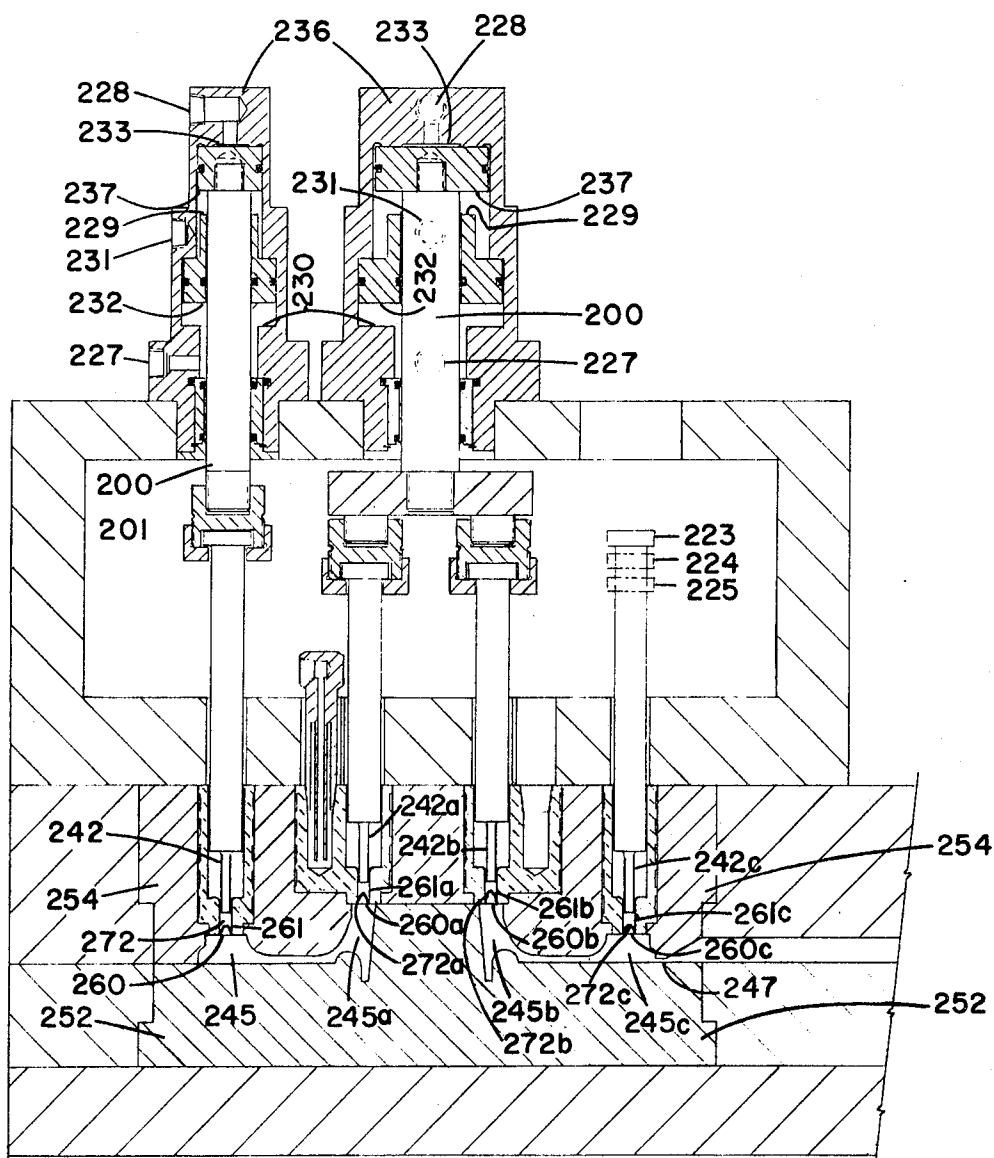


FIGURE 3

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DIE CASTING DENSIFIER AND EJECTOR APPARATUS

This invention relates to casting apparatus and, more particularly, to casting apparatus for casting various types of metals and alloys, including ferrous metals, to improve the quality of the cast product. Still more particularly, this invention relates to apparatus for die casting, permanent molding, and low pressure casting, and especially to such apparatus which produce castings with substantially uniform density throughout.

It is well established that in casting many types of metals and alloys (hereafter together called "metals"), the change from the liquid state to the solid state is generally accompanied by a substantial contraction in the volume of the metal. It is known that the contraction occurs, not only during the shrinkage of the liquid as the temperature of the casting liquid is reduced before solidification starts, but also due to shrinkage arising from the contraction or freezing of the metal in changing from a liquid state to a solid state during the casting operation. In actual fact, the shrinkage or contraction of metal in changing from the liquid state to the solid state to yield a casting may range from about 2 percent to about 10 percent of the total metal volume. Because of these unavoidable shrinkages and contractions, castings produced by conventional methods and apparatus often are of a somewhat porous nature and contain voids formed within the casting body proper. The shrinkage and contraction may, as is frequently the case, introduce a number of void spaces, not only small spaces but even fairly large ones, and such voids may be dispersed into various regions of the final casting, some reaching to the surface of the casting. The number and size of the pores and voids in the final casting quite naturally adversely affect the quality, uniformity and strength of the cast product, and may also affect the utility and salability of the product.

In order to avoid the production of such porosities and voids, so-called runners and riser arrangements are presently employed in and with conventional casting machines and processes for maintaining a good supply of fluid metal adjacent to the casting and for ready supply to the casting during the entire period of time required for the casting to become fully solidified. Metal in the runners and risers, fed in an over-supply to the casting cavity, is intended to compensate for and to overcome the resultant and unavoidable changes in the volume of the metal during its conversion from the liquid state to the solid state, and to overcome and eliminate the porosities and voids, and to achieve thereby a higher and more uniform density in the final casting product. The excess metal supplied to the runners and risers, in many cases, may approximate 50 to 60 percent of the total volume of the metal poured into the casting mold. Notwithstanding these remedial operations, the presence of internal voids in the casting are not always overcome by conventional casting methods, especially in areas of the casting that are somewhat remote from the runners and risers. In any case, there will be a wastage of material and a loss of time in manufacturing the casting product with the excessive use of runners and risers and naturally the cost of production of the castings will be considerably increased. It is also recognized that these conditions may be somewhat alleviated by the use of extra heavy sectional thickness placed strategically to promote feeding of shrinkage — compensating liquid metal to these remote areas from the over-supply present in the risers and runners. These thicknesses, commonly called "padding" in the industry, are recognized to add substantially to the final casting weight and therefore increase cost.

In accordance with the present invention, metal is to be fed to the casting space of a mold in about the proper amount required not only to fill the casting space but also to form a nib or projection adjacent to and above the critical casting space to compensate for changes in the volume and uniformity of the cast material as it is transformed from its liquid state to the solid state. Moreover, the exterior nib or projection can be allowed either to partially solidify or totally harden and then it will be driven into the casting space and thereby added to and intimately mixed with the internal casting material in the

remaining regions where the casting metal will be in its liquid or semi-liquid form. Thus, the metal of the external projection will be supplied to the casting space before or immediately after all of the metal within the space is fully solidified, whereupon the projected metal will be forced into the porous and cavitous regions in the locale of the point of application in order to achieve a relatively high density throughout the adjacent casting space. By practicing this invention, there will necessarily be an increase in the acceptable casting yield of the manufactured product and a minimum of wastage or loss of material, and this will be due to the more efficient and properly timed utilization of of predetermined amount of added feed metal to compensate, as closely as possible, for the shrinkage and other voids which would otherwise be formed in the product. Thus, the product will be created with the practical minimum of surplus metal remaining on hand to be removed from the casting and re-melted after the shape has fully solidified.

It is one of the principal objects of this invention to produce a casting of substantially uniform density, substantially free of voids or the like arising from uneven contractions of the molten material which has been poured into the casting mold.

Another of the objects of the invention is to produce a casting of substantially uniform density by adding some material to form a nib or projection on the surface of the casting with additional metal supplied to the mold and then driving the added material into the casting space so as to re-distribute the material within the mold space to overcome voids and other irregularities therein.

These objects may be achieved in accordance with this invention by providing a minimum of two openings or apertures to the casting space within the mold, one opening or aperture to permit entry of the molten material to be converted into the desired casting within the mold and the other opening or aperture to receive, via the casting space, a sufficient amount of metal to form a nib or projection of somewhat predetermined shape and volume, which, when hardened sufficiently, will be driven or pressed into the casting space to reorganize and reshape the material within the casting space so as to improve the uniformity of the density of the casting material by reducing or eliminating the voids within the solidified casting.

The present invention, together with its objects and features, will be better understood from the more detailed description hereinafter following when read in connection with the accompanying drawing in which:

FIG. 1a is a cross-section showing, in schematic form, the basic components of some of the apparatus for carrying out the casting process of this invention;

FIG. 1b schematically shows a cross-sectional view of a part of a machine for densifying castings in accordance with this invention;

FIG. 1c shows a plan view of one form of casting pattern illustrating certain densification points;

FIG. 2 schematically shows a cross-sectional view of a different embodiment of the machine of this invention which employs a plurality of compaction cylinders and a plurality of ejection cylinders; and

FIG. 3 illustrates a further embodiment, in cross-section, this machine employing a dual acting cylinder arrangement.

Referring to FIG. 1a, there is schematically shown the basic parts of a system for use with molding apparatus according to this invention to produce a simple cast product, such as a brass hanger bracket. The part 10 may be a typical random commercial casting which, if made according to conventional processes, would be expected to contain a number of internal imperfections in the form of holes, spaces, etc., sometimes hereafter called voids, which are inherently due to shrinkages and usually are difficult to avoid in the casting of brass and other metallic articles in permanent metal molds. The shrinkages in such materials, which may well exceed 5 percent, arise from the contractions in the molten liquid while passing into its solid state and are due principally to volume changes as the temperature falls. The article 10, may, for example, have sub-

stantially parallel walls 12 and 14, and would inherently or necessarily embrace one or more of such voids which would be of various shapes and sizes, especially if there was not available feed metal together with apparatus conforming to this invention and used during the casting process, for supplying such material for insertion into the molding space to compensate for the shrinkages due to changes arising from the metal in passing from its liquid state to its solid state. Such voids naturally impair the uniformity and quality and strength of the product and, of course, adversely affect its utility and perhaps also its salability.

In FIG. 1a, the external mold for yielding the product 10 is not shown but it would include the densifier apparatus (to be described) in the preferred configuration of this invention. The mold would have a densifier hole or aperture 16. The hole 16 in the mold constitutes an opening to a bore 20 of the apparatus. The apparatus includes a rod 22 which may be moved within an alignment cylinder bore 21, as may be desired. As the casting material enters the cavity ingate or opening (not shown in FIG. 1a) and partially solidifies in the molding apparatus, some of the casting material will be readily forced through the hole 16 and into the bore 20 so as to form a nib or projection 24. The metal entering the bore 20 from the molding cavity will normally solidify more rapidly than the metal in the cavity because of forced cooling on the densifier block and the large ratio of mold area to casting mass, so that the nib or projection will be quickly formed as an appendage to the casting material within the casting space. The densifier apparatus will then be caused to operate in a carefully timed relation to the rate or phase of the solidification of the nib 24, which is made of the same material as the product 10, so as to move the rod 22 into direct and intimate contact with the nib 24 and thereby to drive the material of the nib 24 back into the casting 10.

The main objective is to drive the nib material 24 into the casting space 11 in and near the region where the metal of the casting is in its most fluid state. This is usually the region of the highest temperature. Hence, the material driven back into the casting space will be expected to re-arrange the material therein so as to fill the void or voids in the nearby regions thereof, thereby yielding a casting of substantially uniform density throughout and free of voids. It will be apparent that the densifier apparatus may incorporate any number of rods 22 or like elements for simultaneously forcing a series of nibs or projections, such as 24, back into the mold so as to simultaneously overcome void formations and other density imperfections due to shrinkages in a plurality of so-called "hot spots" within the molding space. The practice of this main objective has special economic importance in that the benefits of high casting density can be achieved, if desired, in areas remote from the conventional gating and riser systems associated with normal commercial practice. It is recognized that equivalent density can be achieved corresponding to that developed by practice of this invention, by increases in the conventional gating and riser systems and by casting design changes to promote directional solidification toward the gates and risers. These conventional methods require substantially more metal either in the castings or in the gates and risers, reduce production rates on the equipment, and correspondingly generate increased costs in the final product.

Thus, it is another of the main objects of this invention to employ a densification or compaction equipment in conjunction with a casting mold so as to compensate, as closely as possible, for the inherent and unavoidable changes in the casting material caused by contractions occurring in the mold system in the production of a casting.

FIG. 1b schematically depicts, in cross-section, a portion of a machine employing a single action cylinder for densifying and casting operations. The machine is capable of simultaneously densifying the casting from several remote points, along the suggested lines previously described. The machine includes a single action cylinder 41, but, if desired, two or more densification cylinders, such as cylinder 41, may be employed,

either singly or in conjunction with each other, to produce a single casting. Six cylinders may be required to produce the casting structure shown in FIG. 1c. However, four so-called densification rods 42, 42A, 42B and 42C are shown in FIG. 1b for illustration and they are aligned by alignment cylinders 43, 43A, 43B and 43C, respectively. Two other points for densification 42D and 42E are shown in FIG. 1c, but are not depicted in FIG. 1b, for convenience. The part of the machine shown in FIG. 1b in cross-section merely illustrates the four densification cylinders and points which are aligned along the centerline A—A of FIG. 1c.

FIG. 1b schematically depicts a portion of the permanent mold and casting equipment that may be used to produce a single casting product similar to the one shown in FIG. 1c. Any other product, whatever its shape, may be produced with a machine employing the principles of this invention. Molten metal derived from an appropriate furnace (not shown) and delivered through a pipe or conduit may be introduced into the cavity 45 through an opening or gate 47 which is located at the parting line 49 between adjacent mold segments or blocks 52 and 54. The molten metal flows freely through the cavity space 45 until the casting cavity 45 is filled. The pressure of the molten fluid is sufficient, however, to cause the metal moving through the cavity space 45 to enter the four densification openings 60, 60A, 60B, and 60C in appropriate volume to form nibs or projections 72, 72A, 72B, and 72C in bores 61, 61A, 61B and 61C respectively. The molten metal in the casting cavity 45 then becomes partially solidified and can form a coating or skin of solidified metal, such as is shown at 62 in FIG. 1a, for example. The skin 62 generally surrounds the liquid metal as it sets in place, the inner region of the metal being designated 11 in FIG. 1a. In general, there is a temperature gradient which is approximately proportional to the section thickness of the casting mass that is solidifying.

As soon as the metal has solidified sufficiently, aided by the cooling effect of the several densification blocks 55, 55A, 55B, 55C, the several corresponding rods 42, 42A, 42B and 42C connected to cylinders 41 will be activated by a separate hydraulic system (not shown) which feeds the hydraulic fluid to each cylinder 41 so as to drive each rod actuator 70 and the piston head 71 and the corresponding rod 42 down. Each rod 42 will move in the corresponding aperture 61 and apply adequate mechanical pressure to the nib or projection 72 to force the material in the nib or projection 72 through the aperture 60 and into the cavity space 45, in the manner previously described in connection with FIG. 1a. FIG. 1a generally shows the casting cavity in an enlargement of a portion of that shown in FIG. 1b.

According to the invention, the movement of the rod 42 in the alignment cylinder 43 is timed to coincide with the requirement of the metal solidifying in area 45 so that the metal in the nib 72 may be driven into the relatively "hot spot" of the previously poured material within the casting cavity 45 to fill all of the nearby voids of the poured material before full solidification and thereby compensate for shrinkage developed under the changing thermal conditions accompanying the solidification of the molten liquid into the solid casting. If allowed to occur, the shrinkage may vary, as already noted, between 2 percent and 10 percent of the total volume of the metal within the casting cavity 45. The amount of the metal poured into and provided by the nib or projection 72 is designed or calculated or adjusted to be sufficient under the prevailing conditions, to approximately compensate for the voids or porosities expected to be encountered within the cavity 45.

In accordance with this invention, the volume of metal required in the densification process, that is, the metal poured or pressed into the nib 72 for re-entry back into the casting cavity space 45, may be controlled and adjusted to the desired or predetermined amount commensurate with the particular cavity spacing and its contours, and commensurate also with the metals and other materials used, the thermal conditions and the other parameters of the construction. A threaded

locknut arrangement 76 serves as a convenient adjusting means for this purpose. Thus, the quantity of metal allowed to enter the densification bore 61 may be varied, for example, by trial and error during pre-production evaluations and planning. The adjustment of the locknut mechanism 76 controls the spacing between the end of the cylinder rod 42 and the parting line 49 separating the mold blocks 52 and 54. By careful adjustment, the amount of material supplied to the nib 72 should be just sufficient to achieve the required reinsertion of metal to overcome the voids that would otherwise form in the casting. If a surplus should perchance appear, the surplus may be removed in any well known manner after the casting is ejected from the mold. If, in the pre-production trials, an inadequate quantity of material is provided in the densification nibs 72, then the locknut adjustment mechanism 76 may be retracted to increase the spacing between the end of the rod 42 and the line 49 so that more metal may be inserted into bore 61 for the densification process. The diameter of the densification opening 60 through which metal is supplied to form the nib 72, will be sized to take into account the expected shrinkage of the casting material during solidification. Thus, substantially the right amount of material will reach the apparatus and, upon compaction, the nib 72 will not need to be driven into the cavity space 45 beyond the parting line 49.

The molding block 54 is shown backed and supported by a so-called back block 78. The cooperating molding block 52 is also backed and supported by a block 80 which may, if desired, form part of a casting ejector mechanism (not shown) which may be of any well known type. Block 52 may be separated from block 54 so that the hardened casting formed in cavity 45 may be removed from the mold cavity and the densification apparatus after completion of the compaction process.

Although the structure shown in FIG. 1b embodies four aligned densification cylinders such as 41, additional cylinders of similar construction may be mounted also on both sides of the parting line 49, thereby to accommodate any number of densification cylinders. Coacting cylinders may also be employed for feeding material to the same point or region for pressing nibs, such as 72, from the two opposite sides of a casting cavity so that voids may be eliminated by pressures from opposite directions in the same general casting region. In other words, densification, according to this invention, may be applied to two or more coinciding points in a particular equipment to accomplish any desired degree of densification at any point or region within the casting.

The various parts of the densification mechanism shown, for example in FIG. 1b, may be arranged and coordinated to compensate for differences in thermal expansion produced by temperature differentials common to the particular die or mold system such as the one described and explained in connection with FIG. 1b and to the molten metals supplied thereto. For example, the mold block 54 may reach and maintain a temperature of about 400° F. while the adjacent back block 78 reaches a temperature of about 300° F. The higher temperature would be developed in the mold block 54 because it is adjacent to the molding cavity 45 through which contains the very high temperature molten metal. However, compensation may be effected, and is effected, with the equipment of this invention to avoid or preclude mis-alignment of the equipment and to prevent distortions and false or inaccurate operations of the equipment. Because of the differentials in temperature between, for example, the back block 78 and the relatively warmer mold block 54, a greater thermal expansion would occur in the block 54 than would occur in the back block 78. Such a difference in thermal expansion could create the undesired mis-alignment, thereby throwing the rod 42 and its aligning cylinder 43 out of alignment to a sufficient extent with respect to the projecting nib 72. Any such mis-alignment, if allowed to occur, would produce a binding effect on, and a seizure of, the moving piston and rod parts due to the thermal changes. In accordance with this invention, this adverse effect may be reduced, if not overcome, by a ball 82 and related

mechanism which are provided between the member 70 and rod head 84. The rod head controls the movement of a retainer member 86 which holds spring 88 retracted in position within the cylinder 41. Hence, the rod 42 will be caused by this mechanism to move in a substantially linear direction, always properly aligned and centered, and the linear movement will be unaffected by the aforementioned temperature variations of the heated parts such as 54 and 78. By preserving the linearity and thereby preventing the mis-alignment of the moving parts of the densification equipment, the arrangement is capable of applying steady pressure to the nib 72 and squarely directing it in its appropriate path to drive the nib through aperture 60 into the cavity 45.

The stroke and operation of the rod 42 in its alignment cylinder 43 may be controlled and activated by hydraulic pressure supplied through an opening 90. The hydraulic fluid may be of any type, whether gaseous or liquid; the fluid may be oil, for example. The application of the hydraulic fluid through the opening 90 will act against substantially all of planar surface of the piston 71 and will thence move the rod actuator 70 and its rod 42 down to provide the force or blow against the nib or projection 72 so as to drive the projection 72 into the casting space 45. The stroke of the rod 42 is timed and controlled by external valving mechanism (not shown), which may be of any suitable or well-known construction, to complete the compaction function. Upon the completion of the densification stroke of rod 42, the hydraulic pressure previously applied through opening 90 will be released. Immediately upon the release of the hydraulic pressure on the head 71, the rod actuator 70 will be returned to its initial position. Spring 88, which is held within retainers 85 and 86, is compressed when the rod 42 is moved in the direction of the projection 72, but this spring thereafter serves to move the piston structure to the right to return it to its normal position. However, it is understood that this return stroke may be generated by other means well known to the trade, such as by pneumatic or hydraulic means. Thus, the densification rod 42 and the rest of the assembly will be prepared for the next casting production cycle which may be initiated just as soon as the solidified casting has been removed from the casting cavity 45.

Thus, molten liquid will be initially poured into the casting cavity 45 through the entrance opening 47 to fill the casting cavity 45 and some of the metal will then be caused to move out of the casting cavity 45 to provide the nib 72 within the cylinder bore 61. The metal forming the nib 72 will be allowed to solidify or harden to respond to the rod 42 in the densification cycle when the piston 70 is activated, whereupon the nib 72 will be driven back into the cavity space to supply the semi-hardened metal for accomplishing the desired elimination of the voids within the casting space 45. The cyclical operation may be controlled by the hydraulic mechanism attached to entrance port 90 and the valving structure may be timed, for automatic operation wherever desired, to repeat the operation at regular intervals.

The blocks 52 and 54 which, when assembled as shown to provide the casting space 45, may be made of any of the conventional die materials. The block 55 may be of similar materials or preferably a high thermal conductivity material such as copper, molybdenum, or tungsten or their alloys. The block 55 also contains a series of milled pads or openings 94 to provide air gaps designed to retard the transfer of heat from the mold inserts into the densifier block 55. Other methods of insulation may also be used. Air employed for cooling purposes may be blown into the spaces of the densifier block 55 through an opening 95. The flow of the cooling air is controlled or sized by any form of needle valve 96. The air so admitted enters the block 55 through a tube 97 which provides a cooling medium, not only to cool the block 55, but also to cool the nib or projection 72 within aperture 60 before the metal in casting cavity 45 has also cooled. The cooling effect of the supplied air will help to partially solidify the material 72 so that it may be forcefully driven into the cavity 45 by the rod 42 and will minimize flash between the sidewalls of the aperture

and the rod 42, that would impair repeated operation of the apparatus. The cooled air may be exhausted through an air passage 98 which may lead to the atmosphere. If desired, any other cooling medium may be employed for this purpose; water, for example, may be fully adequate in many cases, but would require minor apparatus modifications to permit sealed entry and exit of the cooling medium if a medium other than air is used.

The rod 42 is proportioned to fit fairly closely the bore 61, and the aligning cylinder 43, to assure that the projecting material 72 can be fed into cavity 45 within a fairly wide range of plasticity of the material 72.

The densifier blocks 55 are shaped and proportioned so as to fit conveniently into the assigned spaces in the mold insert block 54 and can be held in place by the back block 78.

FIG. 2 schematically illustrates an arrangement in which each of the rods 142 perform two distinct sequentially time functions:

1. It drives the nib or projection 172 into the cavity space for densification. The timed 172 is formed on the outer surface of the casting cavity 145 (as in the case of FIG. 1b) which was previously described; and

2. It thereafter ejects the finished casting from the casting cavity 145 after the casting in cavity 145 has solidified.

Only the essential components of the densification machine are schematically illustrated in FIG. 2. The other operative components would be obvious to those skilled in the art after a reading of this specification.

In FIG. 2, there are shown two compaction cylinders 140 and 140a and two ejection cylinders 141 and 141a. The compaction cylinder 140 controls a piston 100, which is coupled by means of a coupler 101, which is joined to the compaction rod 142. As previously explained, the rod 142, which is shown in its normal position ready to proceed to compaction, may be moved down from its compaction position so as to drive the nib or projection 172 through the opening 160 into the cavity space 145, thereby causing the material of the projection 172 to mix with the material within space 145 to thereby change the density of the casting material contained within the cavity space 145. This additional material will remove the voids in the adjacent region of the cavity space 145. The compaction rod 142 includes a head 103 which is positioned and held between the body 104 of the coupler 101 and an internally threaded retainer 105 so that the compaction rod 142 and the coupler 101 may operate in unison. Attachment cavity 106 of the coupler 101 is threaded to engage the externally threaded rod 100 of the cylinder 140 so that the coupler 101 will move in unison with the piston 100 and compaction rod 142. Thus, each movement of the cylinder 140 will produce a corresponding movement of the member 142 which then makes direct contact with the projection material 172 to drive it into the cavity space 145. Each coupler arrangement, such as 101, serves to maintain the correct alignment of the rod 142 within the aperture 161 as temperature changes occur so that the rod 142 will make direct and intimate contact with the projection material 172 as the rod 142 is driven down for the purpose of compaction.

The compaction cylinder 140a and its piston 100a similarly control the two coupling mechanisms 101a. In this case, two coupling mechanisms 101a are employed instead of one and their functions are substantially the same as those associated with coupling mechanism 101 of cylinder 140 previously described.

FIG. 2 shows a relatively large H-carrier block 110 which includes a bottom segment 111, a top segment 112 and a cross segment 113. Both compaction cylinders 140 and 140a and both ejection cylinders 141 and 141a are connected to and supported by the H-shaped carrier block 110. The carrier block 110 holds and supports the several compaction and ejection cylinders. As will be apparent from FIG. 2, the H-shaped carrier block 110 is mounted within a relatively larger U-shaped block 115. This U-shaped block 115 provides a basic support so that the movements of the compaction and

ejection cylinders are held in their relative positions in the mechanism.

As in FIG. 1b, the adjacent blocks 152 and 154 constitute the severable mold components for the mold system having the cavity space 145. The two blocks 152 and 154 have their parting line 149 about which the blocks may be separated from each other. The block 152 must be displaced from the adjacent block 154 when the finished castings are to be ejected, and the block 152 must be returned to the position indicated in the drawing when another casting cycle is to be performed on another series of castings.

In the so-called fill position of the mechanism, the compaction rod 142 and the ejection cylinders 141 are in their respective retracted positions — which positions are shown in FIG. 2. This fill position is schematically or graphically depicted by the block 123. During this fill cycle of the operation, molten material may be fed from the reservoir of a furnace such as an electric furnace, through a conduit (not shown) to the gate or entrance 147, the molten material being fed from the furnace to opening 147 at any pressure desired. The molten material will fill the cavity space 145, having reached the cavity space 145 through the openings 147 to the cavity space 145. The pressure applied to the molten material should be sufficient also to cause some of the molten metal to fill the aperture 160 of the cavity space 145 so as to establish each of the nibs or projections 172, as previously explained. The mechanism is now ready for the compaction cycle.

During the compaction cycle, the compaction cylinders 140 and 140a are caused to move down. This lower position is symbolically represented by the compaction position 124 shown in FIG. 2. In this position each compaction rod 142 will contact the corresponding projection 172 which has frozen or partially solidified, and the pressure applied to the compaction rod 142 will drive the material of the projection 172 through the port 160 into the cavity space 145 to reach the so-called "hot spot" within the cavity space 145. This will remove the voids in the region of the hot spot and thereby rearrange the material within the cavity space 145 so as to render the density of the material substantially uniform throughout the region. This will end the compaction cycle.

In order to eject the finished casting from the cavity space 145 after the casting material has hardened sufficiently, the block 152 must be severed from the block 154. Immediately thereafter, the H-shaped carrier block 110 will be caused to move down by pressure applied to the ejection cylinders 141 and 141a. The ejection position will symbolically correspond to the block 125, shown in FIG. 2. The end of the rod 142 will extend through the aperture 160 so as to eject the casting from the cavity space 145. This will end the ejection cycle, and cylinders 141, 141a, 140 and 140a will retract to their starting position to prepare for a new cycle. The block 152 will then be returned to its position as shown in FIG. 2, whereupon the mechanism will be ready for the next cyclical operations in producing another casting or series of castings.

In order to cool the densifier block 155 during the cycle of operations, air or any other cooling medium may be transmitted through the opening 130, then through its passages 131 and 132 and out through the passage 133. The cooling medium is thus released to an appropriate exhaust chamber or into the atmosphere. The effect of the cooling medium in the region of the bore 161 is beneficial to the speedy formation of a partially solidified nib or projection 172 for densification of the casting material.

The movements of the compaction cylinders 140 and the ejection cylinders 141 are controlled by hydraulic pressures which may be developed with the mechanism in any manner well known in the art. The hydraulic pressure is used not only to advance the cylinders in one direction, i.e., down, for compaction and then for ejection, but also to reverse the movement of the cylinders to return the cylinders to their fill positions for the start of the next operating cycle.

FIG. 3 illustrates a schematic of another form of casting densifier system in which a single dual-acting cylinder

mechanism combines the functions of the compaction cylinder mechanisms 140 and 141a of FIG. 2. Here again only the essential components of the overall mechanism are shown, the other components being readily understood by those skilled in the art from the earlier description.

Referring to FIG. 3, a single dual acting cylinder mechanism 236 is shown in a composite view. The mechanism of this illustration performs its operations, as does the mechanism of FIG. 2, on molten metal in the cavity space 245 of the mold system. The cylinder mechanism 236 will be operated to drive the nib or projection 272 of jelled material into the space 245 of the cavity for improving the density of the material fed into the cavity, and then to eject the casting after it has solidified.

The mechanism of FIG. 3 is shown at its initial or fill stage at which molten material may be supplied to the mold system. The molten metal will enter an opening port 247 which leads to the cavity space 245 of the mold system; and, after the molten material has filled the space 245 and entered the aperture 260 of the cavity space 245, there will form a nib or projection 272 as previously described. The filling operation will then be completed.

At the outset, before the rod 242 is allowed to move to the right to drive the projection 272 into the cavity space 245, hydraulic pressure will be supplied from a fluid source to the port 227. This pressure will be applied to the walls 230 and 232 of the cylinder rod 200 to maintain a relatively wide and constant separation between these two walls to hold the cylinder in its fill position (223). While this pressure remains applied to the port 227, the same or a similar pressure will be applied to another port 228 which will act on the wall 233 to start the compaction cycle. In response to the pressure applied through the second port 228, the cylinder rod 200 will be moved down through a predetermined distance to the compaction position (224). Inasmuch as the cylinder rod 200 is coupled by coupler 201 to which the compaction rod 242 is affixed, the rod 242 will be advanced through the aperture 261 to reach the opening 260 into the cavity 245. The movement of the compaction rod 242 through this path will drive the nib or projection 272 into the adjacent cavity space 245 toward the hot spot therein, so that the material of the projection 272 will be mixed with the other material in the same region and thereby substantially eliminate any of the voids in that region. The blocks 223 and 224 figuratively represent the advance of the rod 242 for compacting the material of the projection 272 into the casting material of the space 245. The forward thrust of the cylinder 200 will be stopped when the surface 237 has contacted the surface 229. When the surfaces 237 and 229 are in contact, timing mechanism (not shown) will cause the port 231 to be vented to the atmosphere or to an appropriate drain tank to release the pressure previously supplied to the port 228.

The mold parts 252 and 254 are then separated from each other in any well known manner to permit the solidified casting to be ejected. But ejection of the casting only occurs upon a further advance of the rod 242 through the bore 261. To accomplish the ejection of the finished casting, the initial holding pressure supplied through port 227 will be released, whereupon the cylinder 200 will be advanced further down, equally advancing the rod 242 and causing the rod 242 to extend through the opening 260 and eject the casting within the casting space 245. The movement of the rod 242 will be arrested when the wall 232 meets the wall 230. The ejection position is generally shown by 225.

To return the mechanism to its original or fill position in preparation for another filling of molten metal into the casting space 245 at the beginning of the next cycle, it is necessary to release the pressure previously supplied to the port 228 and at the same time to again apply pressure to the port 227 in order to disengage the surface 232 from the surface 230. At this time, the port 231 is vented either to the atmosphere or to an appropriate hydraulic tank. The rod 242 will be returned to its normal or fill position, prepared for the next cycle. The block 225 shows the point of greatest advance of the rod 242 and the

related mechanism for the ejection of the completed casting. The complete return of the cylinder 200 to its original or fill position is accomplished by again applying pressure to the port 231 in order to space the wall 237 from the wall 229. When this is completed, the next cycle of the sequential operation may be undertaken.

FIGS. 1b, 2 and 3 of the drawing show conventional O-rings at places where it is important to prevent the leakage of fluid. In FIG. 1b, for example, two O-rings are shown. It seems unnecessary to relate the locations and purposes of the other O-rings in the other figures.

While this invention has been shown and described in relation to the production and manufacture of metal castings which may be made of any metal, such as ferrous metal, aluminum, etc., the invention is equally applicable in the production and manufacture of non-metallic castings such as plastic parts and products.

The parts of the overall mechanism are proportioned and arranged so that desired temperatures are maintained at critical points in the organization where, for example, compaction is intended to take place. It is important that molten material fed into the entry aperture 47 of FIG. 1b reach the cavity space 45 and fill the cavity space 45 completely before the densification cycle is initiated. It is also important that another or second port 60 be provided adjacent to one or more hot spots within the cavity space 45 and that the pressure applied to the molten material be sufficient to drive some of the molten material through the port 60. It is equally important that the material fed through the port 60 form a projection which may be driven back or returned through the second port 60 to intimately contact the material in the adjacent region of the casting space 45 to produce the required uniformity in the density of the casting material.

It is important that the mechanism controlling the movement of the rod 42 be maintained rather fully compensated against the temperature and other parameters which might affect the direction of movement of the rod 42 and which might therefore produce a poor compaction.

These are some of the important factors which are treated in the foregoing application as essential to the production of good castings.

While this invention has been shown and described in schematic form to represent several different embodiments and their general modes of operation, it will be understood that the general principles as well as the objects and features of this invention may be carried out with other and widely varied organizations without departing from the spirit of the invention as set forth hereinabove.

I claim:

1. Apparatus for casting metal comprising a mold having a cavity in which molten metal is to be received, a first aperture in said mold through which molten metal is to be fed to said cavity, a second aperture in said mold for receiving a predetermined amount of said metal after it has passed through said cavity and completely filled said cavity and to form a metallic projection superimposed upon said cavity, said second aperture being positioned adjacent to an enlarged region of said cavity and being non-aligned with said first aperture, means for adjustably controlling and limiting the length of the metallic projection superimposed on the cavity of the mold through its second aperture, means for supplying a cooling medium to those parts of the mold which are adjacent said second aperture to reduce the temperature of said metallic projection below the temperature of the metal within said cavity, a rod-like element which is movable in a direction so as to drive said cooled metallic projection into said cavity after it has been partially solidified to diminish any voids in said cavity, means for delaying the pressing means until said metallic projection has been partially solidified, and means for advancing said rod-like element further so as to eject the casting after it has solidified.

2. Apparatus for casting metal for producing a metallic casting substantially free of voids, comprising a mold having a first

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aperture, means for feeding molten metal into said mold through said first aperture to completely fill said mold and to provide an excess of the molten metal, a second aperture within said mold through which the excess of the molten metal supplied to said cavity is pressed so as to form a projection on the outside of said mold, said second aperture being positioned adjacent to an enlarged region of said cavity and being non-aligned with said first aperture, means for supplying a cooling medium to those parts of the mold which are adjacent said second aperture to reduce the temperature of said metallic projection below the temperature of the metal within said cavity, a rod-like element which is movable through a first predetermined distance to drive said cooled metallic projection into said cavity of said mold, and means for moving said rod-like element through a still further distance so as to eject the casting from the cavity of said mold after it has been solidified.

3. Apparatus for casting metal according to claim 2, including a screw-threaded means coupled to the mold for controlling and limiting the length of the metallic projection superimposed on the cavity of the mold through its second aperture.

4. Apparatus for casting metal according to claim 2 in which the second aperture in said mold is arranged so that the pro-

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jection of material produced adjacent to said aperture is pointed toward a hot spot within said mold.

5. Apparatus for casting metal according to claim 2, in which said rod-like element is moved in a direction which substantially coincides with a hot spot within said cavity.

6. Apparatus for casting metal comprising a mold formed of a plurality of members providing a common cavity space, means including a first aperture in said mold through which is fed molten metal into said cavity space in an amount in excess of the full capacity of the cavity space, a second aperture in said mold which is non-aligned with the first aperture and through which is released the excess of the molten metal so as to form a longitudinal projection of said metal, said longitudinal projection being adjacent to an enlarged region within said cavity space, means for supplying cooling fluid to the region of said mold adjacent said projection for rapidly cooling and hardening said projection without substantially changing the temperature of the metal within said cavity space, piston-like means for driving said cooled and hardened projection into said mold so as to diminish voids therein, and means for further advancing the piston-like means through said second aperture after the members of said mold have been separated so as to eject the solidified casting from said cavity space.

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