

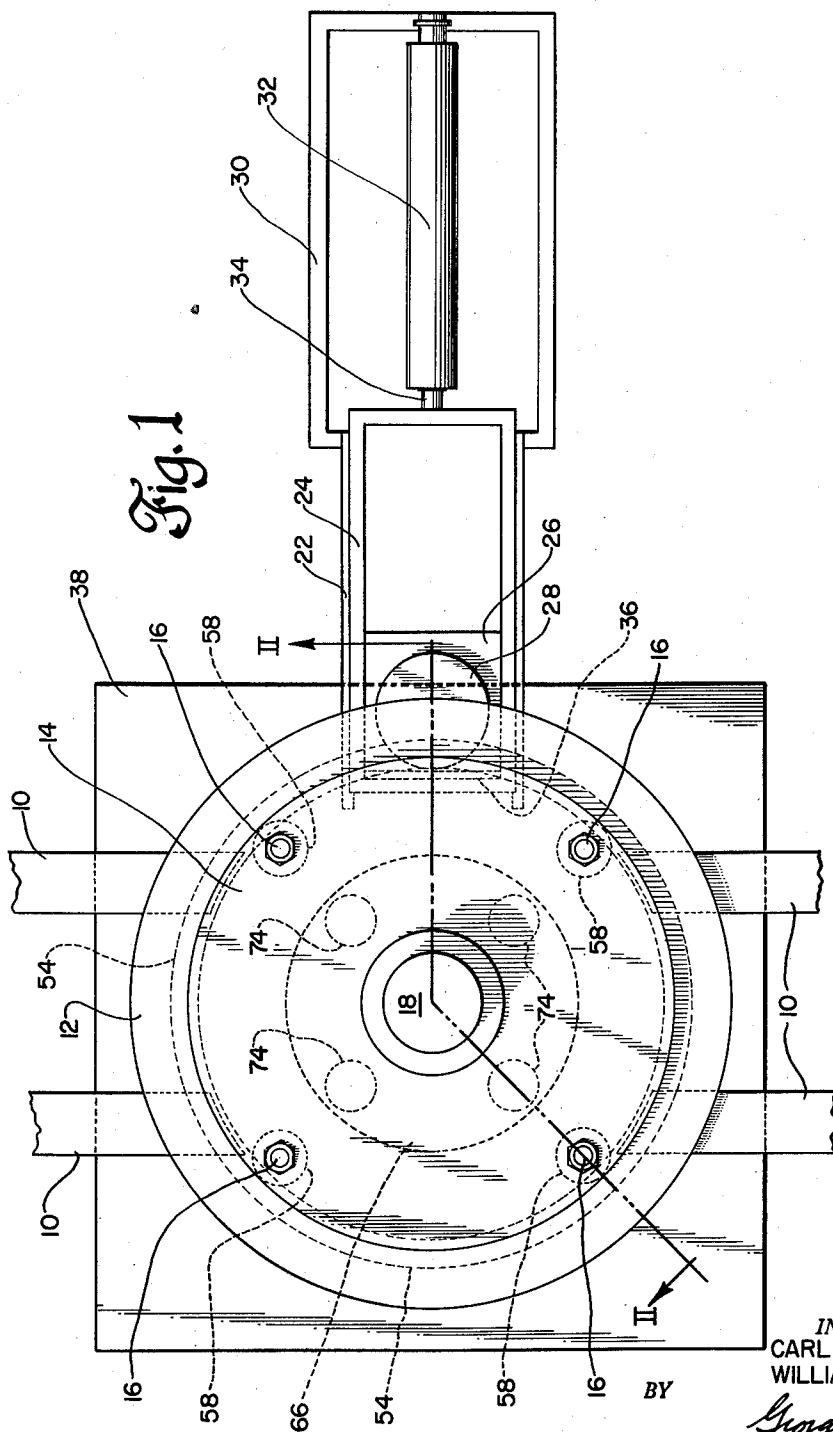
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C. L. GOODWIN ET AL
CASTING PROCESS AND MACHINE

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4 Sheets-Sheet 1



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Fig. 2

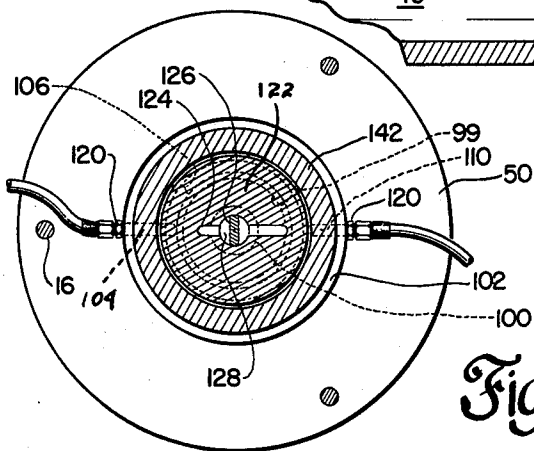
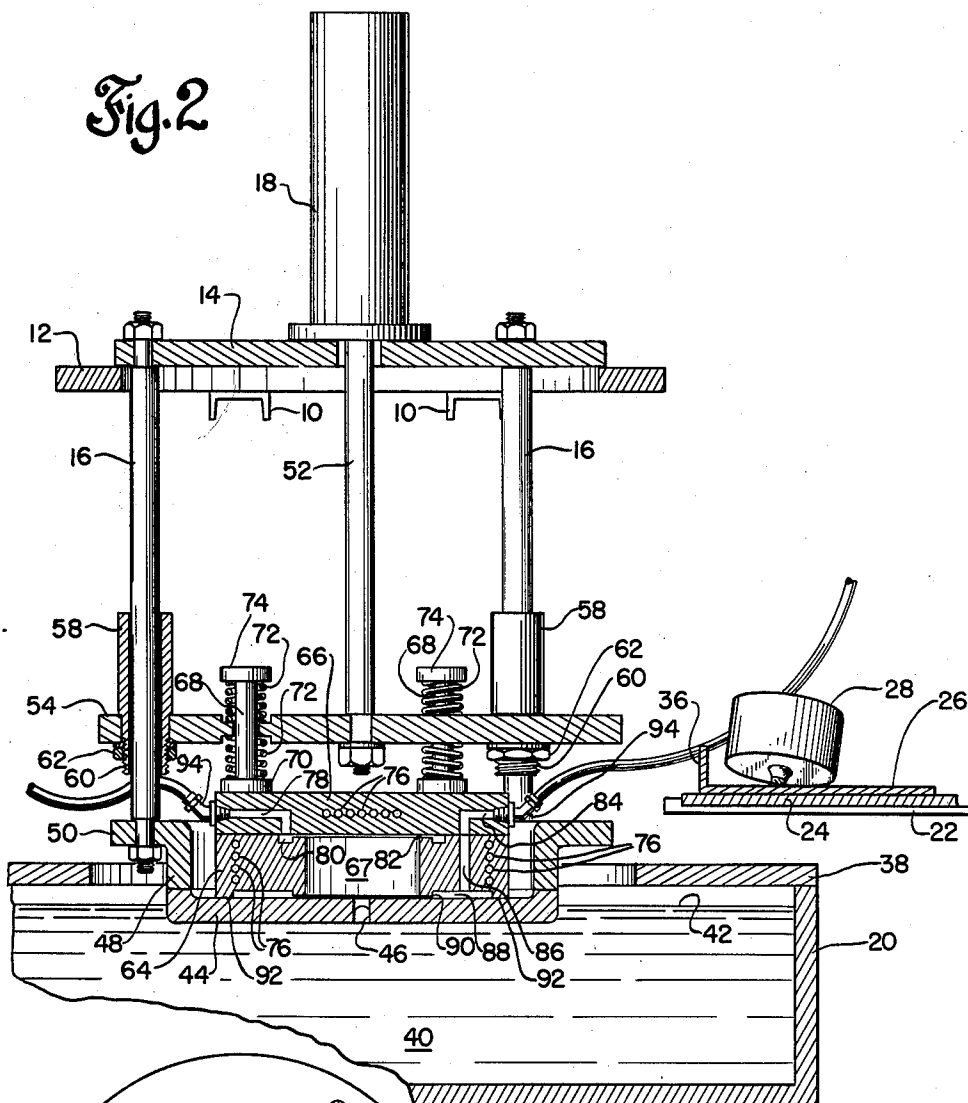


Fig. 6

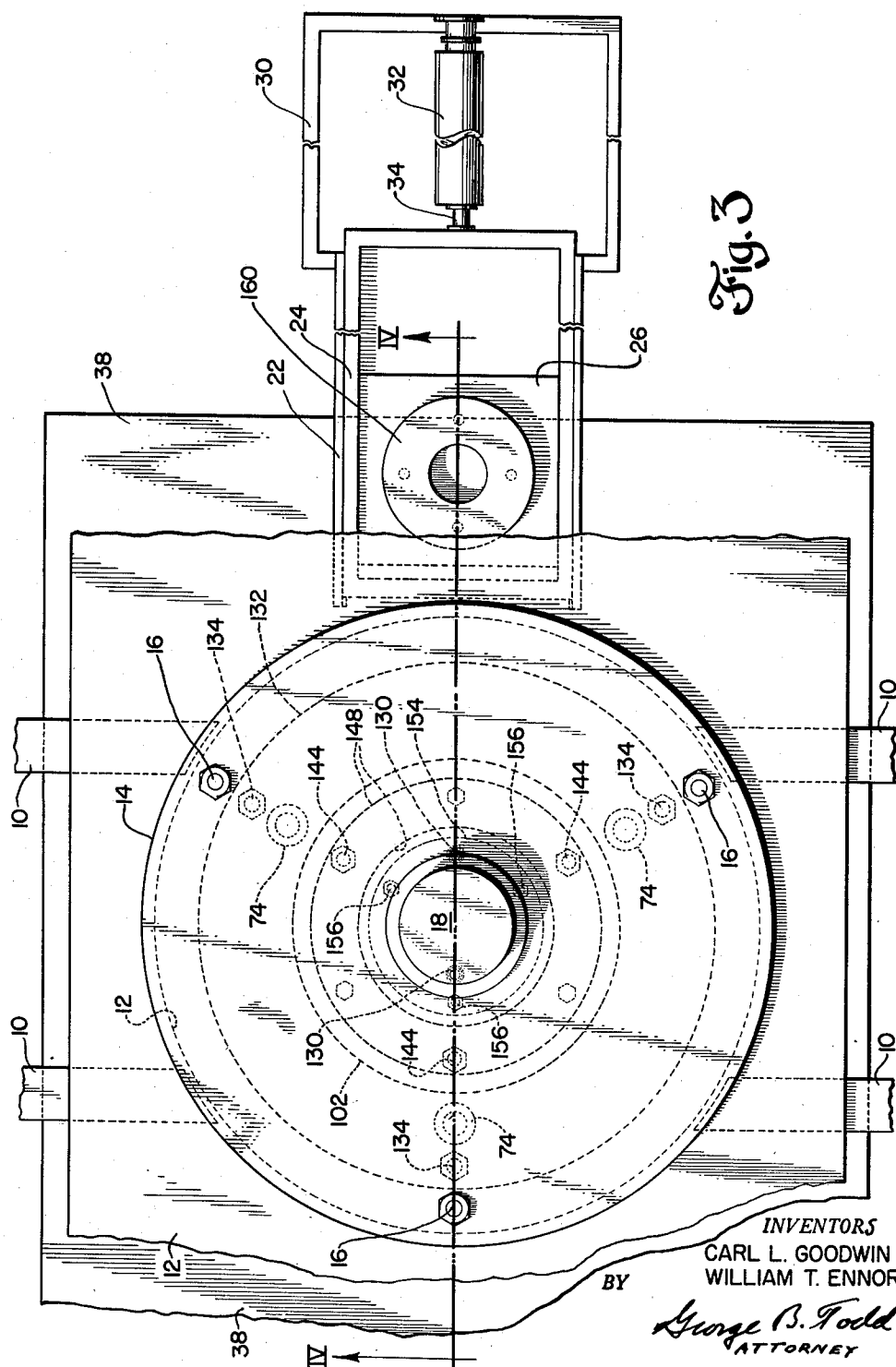
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CASTING PROCESS AND MACHINE

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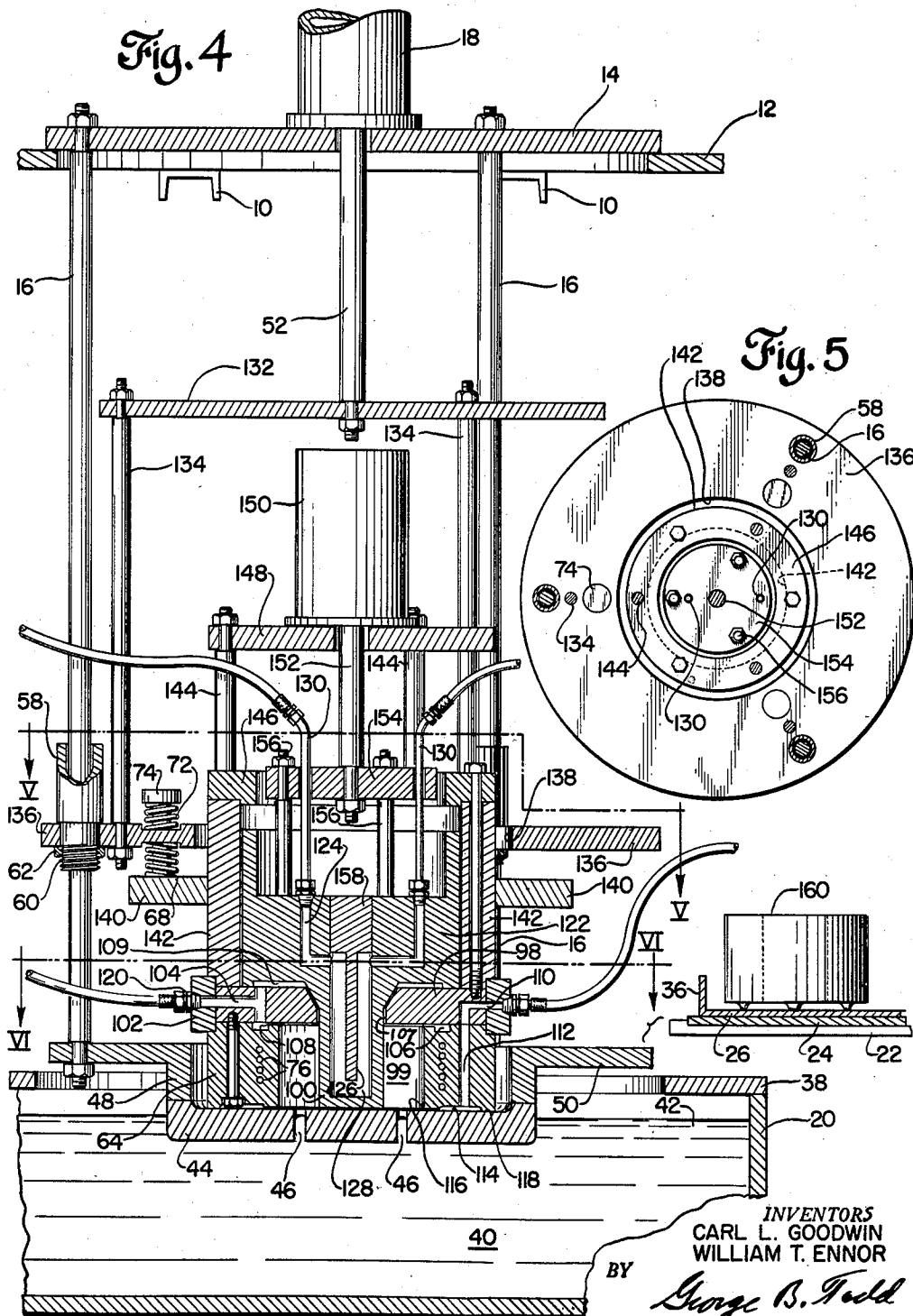
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2,923,040

CASTING PROCESS AND MACHINE

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11 Claims. (Cl. 22—73)

This invention relates to the rapid production of chill castings of the light metals, aluminum, magnesium and those alloys wherein these elements constitute more than 50% by weight of the composition. The term "chill casting" as used herein refers to castings produced in molds, usually made of metal, which cause a rapid solidification of the molten metal poured therein. The cast products may be utilized in the as-cast condition or they may serve as stock for the fabrication of wrought articles, especially those made by the extrusion or forging processes.

To gain high production rates in the manufacture of relatively small castings, it has been conventional to simultaneously cast a large number of units in a single mold and subsequently sever each casting from the common runner or gate and trim off any risers. Separate castings can be made by the die casting process at a rapid rate but it is still necessary to sever the casting from the gates and risers. Also, die castings are apt to contain minute voids which are undesirable where the casting is to be subsequently worked.

Castings have not been used to any extent as stock for the production of impact extruded articles because they have been considered to lack the soundness and uniformity of the conventional rolled plate and rod used for this purpose and have not possessed the close dimensional tolerances required in extrusion slugs. As is well known, impact extrusion slugs are blanked from plate stock, usually in a gang press, or they are cut from rolled or extruded rod. The latter practice is generally used where the height of the slugs exceeds the thickness of plate which can be economically blanked. It is obviously expensive to cast ingots and roll them to plate or rod dimensions or to extrude the ingots into rod before slugs can be cut from the worked stock. Where plate is employed there is the added cost of a high scrap loss resulting from unused portions of the plate. The sawing which is required, when rod is used, is an expensive operation and it generates a scrap material. No casting methods have been devised whereby single castings can be made at a high production rate that have the close tolerances required for impact extrusion slugs, a soundness substantially equivalent to that of rolled plate, and which are substantially free from the conventional gates and risers.

One of the objects of our invention is to provide a method of making exceptionally sound individual castings of light metals which require little or no trimming preparatory to being used. Another object is to provide a method of making dimensionally accurate, sound individual castings of light metals at high production rates. A further object is to provide a method of making in chill molds at a high production rate light metal castings which are substantially free from shrinks, voids or entrapped gas. A particular object is to provide a method for casting slugs suitable for use in making impact extrusions and forgings. Still another object is to provide a method of making individual chill castings of light

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metal by quick progressive freezing of the molten metal toward a bottom gate. Another object is to provide apparatus for the rapid production of light metal castings having substantially no gates attached thereto and having the foregoing characteristics, the apparatus being readily adaptable to automatic or semi-automatic operation.

These and other objects are achieved by the method and with the apparatus described below, certain embodiments of the apparatus being shown in the accompanying partially schematic drawings wherein

Fig. 1 is a top plan view of a casting machine for making solid cast bodies and an associated device for transferring castings from the machine;

Fig. 2 is a side elevation of the casting machine taken on section II—II of Fig. 1 and a partial view of the transfer device;

Fig. 3 is a plan view of a casting machine for making hollow cast bodies and an associated device for transferring castings from the machine;

Fig. 4 is a side elevation of the machine shown in Fig. 3 taken on line IV—IV and a partial view of the transfer device;

Fig. 5 is a cross section of the machine on a reduced scale taken on line V—V of Fig. 4; and

Fig. 6 is another cross section of the machine, also on a reduced scale, taken on a lower plane on line VI—VI of Fig. 4.

In our method, the molten metal is fed under external atmospheric pressure into the bottom of a horizontally parted mold which is partially evacuated during the filling operation. The lower mold portion is held in continuous contact with the molten metal body from which metal is withdrawn to fill the mold cavity while the upper portion is artificially cooled. The bottom of the mold cavity is thus maintained at a relatively high constant temperature and the upper part is kept at a much lower temperature. By holding the mold bottom in contact with the molten metal the latter has but a short distance to rise to fill the mold cavity. As a result of such bottom feeding and short travel of the molten metal there is little or no turbulence, splashing or surging such as characterizes the conventional methods of filling molds. Chilling of the molten metal commences at the sides and top of the mold cavity and progresses toward the bottom gate. The chilling of the mold is preferably effected by circulation of coolant at least within the side walls of the mold body. As soon as freezing begins within the gate aperture the upper portion of the mold with casting therein is raised above the bottom portion which remains in contact with the molten metal and the casting is ejected from the raised mold portion onto suitable means for transferring the casting to a discharge station.

The partial evacuation of the mold cavity and subsequent ejection of the casting therefrom under positive air pressure is effected through connection to suitable pumps or other means of providing the desired pressure with a system of valves to control the evacuation and admission of air. Initially the mold cavity is partially evacuated, the pressure being reduced only about 0.1 to 1.5 pounds per square inch below atmospheric pressure, because such a small reduction in pressure is all that is required to bring about a complete filling of the mold cavity. In the production of certain castings it is desirable to further reduce the air pressure to create a higher vacuum at the top of the mold cavity to hold the casting in the mold when the latter is raised. In some cases this further reduction in pressure is made just after the metal has started to freeze so as to maintain the cast body in closer contact with the top of the mold and thereby increase the rate of heat transfer from the top of the cast body to the mold. Upon comple-

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tion of freezing of the casting, the upper portion of the mold is elevated from the base, and a positive air pressure applied at the top of the mold cavity in place of the reduced pressure with the result that the casting is ejected from the mold. It will be appreciated that the admission and extraction of air from the mold cavity can be effected by automatic or semi-automatic means which are integrated with the movement of the upper portion of the mold. Under such conditions a complete cycle of casting, ejection and transfer of the cast product can be generally completed within a period of from 8 to 200 seconds depending upon the size of the casting. The light metal castings produced in this manner have been found to possess a soundness, density and dimensional accuracy substantially equivalent to that of stock cut from rolled plate or rod. The casting process and the machine are well adapted to the production of light metal cast bodies at a high rate, especially if a plurality of mold cavities are provided in one machine and all are filled simultaneously. Although the process and machine are particularly suited to the production of small castings such as for impact extrusion, larger castings can also be made.

A unique feature of the process described above is derived from the relative orientation of the solid metal (i.e. the casting) to the source of molten metal. Because the solid metal is above the molten metal, the two may be parted easily without use of special valves to stop off the flow of molten metal. A further important and unique feature of the process is to be found in the fact that the metal feeding system is self-metering and supplies only enough metal to completely fill and feed the mold cavity. These features simplify the casting procedure by eliminating the special molten metal pumps, valves and metering devices frequently employed to provide automatic pouring in conventional top-delivery casting practice.

Referring to the controlling features of our process in greater detail, it is essential that the molten metal be fed to the bottom of the mold cavity and that it be moved as short a distance as possible from the source of supply to the mold cavity thus attaining certain advantages in filling the mold cavity as described hereinabove as well as providing for a quick transfer of metal to the mold cavity. This may be accomplished by maintaining the lower portion of the mold in a stationary position in contact with the body of molten metal which serves as the source of supply, but the mold is not submerged in the molten metal to the extent that the molten metal flows into the mold cavity under hydrostatic pressure. Moreover, by keeping the mold bottom in continuous contact with the body of molten metal it is maintained at a constant relatively high temperature close to that of the molten metal. In this manner the gate opening does not become clogged with frozen metal, the molten metal enters the mold cavity with a minimum loss of heat thereby insuring proper filling of the cavity without premature freezing of the metal and a nearly constant temperature gradient is established between the bottom of the mold and the upper portion. By keeping the bottom of the mold in a stationary position there is no disturbance of the metal bath as would occur if the mold or parts thereof were moved into or out of the bath. Furthermore, by submerging the bottom of the mold in the metal bath and feeding the mold cavity from below the surface of the metal bath through a gate in the bottom of the mold cavity, the metal entering the mold cavity is substantially free from dross and oxide skin.

To effect rapid and directional freezing of the metal within the mold, a sharp temperature differential is established and maintained between the upper and lower portions thereof. Contrary to the customary top pouring practice we supply hot liquid metal to the bottom of the mold cavity and compensate for any shrinkage

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resulting from solidification by drawing molten metal upwardly from the source of supply through the gate. The temperature differential is created by artificially cooling the upper portion of the mold and maintaining the bottom portion close to the melting point of the metal being cast. A satisfactory practice is to maintain the temperature of the upper mold portion between about 80 and 400° F. while keeping the bottom, which is in contact with the molten metal, at about 900 to 1300° F. The metal within the mold will still freeze even though the bottom plate temperature is above the melting point of the metal since freezing progresses so rapidly from the top and side walls of the mold. The artificial cooling is conveniently done by circulating water in channels within the mold wall or by providing water jackets around that part of the mold. To effect the desired directional and progressive freezing it is usually advisable to maintain a temperature differential of between about 500 and 1200° F. between the upper portion of the mold and the bottom thereof. Under these temperature conditions, freezing of the molten metal can usually be completed within a period of 3 to 190 seconds depending upon the size of the casting, the alloy and the temperature of the incoming metal. In any case, the freezing must progress fast enough to insure a fine metallurgical structure, a coarse structure being undesirable.

In respect to filling of the mold cavity, this is accomplished by atmospheric pressure exerted on the surface of the body of molten metal in the holding pot and by partial evacuation of the mold as has been mentioned above. We have found that only a slight reduction in pressure within the mold cavity is necessary to cause the liquid metal to flow into it. Ordinarily, the air pressure within the cavity need be reduced only 0.1 to 1.5 p.s.i. below normal atmospheric pressure to effect a complete filling of the mold. In our preferred practice the lowest predetermined air pressure is not immediately established within the mold cavity prior to the introduction of molten metal, but rather it is gradually approached. Thus, the initial reduced pressure is sufficient to start filling the mold but the maximum reduction in pressure is only established after the cavity has been partially filled with the molten metal. Such a gradual change in pressure offers the advantage of avoiding any spurting of molten metal into the mold cavity and it assures an adequate and uniform lower fillet radius at the bottom of the casting. In addition, filling of the mold cavity in this manner tends to reduce the flow lines around the lower periphery of the cast product. In extreme cases such flow lines may be objectionable.

In the production of certain castings, especially those which are solid, i.e. there are no cored portions, it is sometimes desirable to further reduce the air pressure at the top of the mold cavity just after the mold has been filled and a solidified shell has been formed. Such a further reduction in air pressure serves to draw the casting closer to the top wall of the mold and by thus reducing the insulating air gap brings about an increase in the rate of heat transfer and rapidity of solidification of the balance of molten metal in the casting. The latter advantage is only realized, of course, if the higher vacuum is applied before all of the metal has frozen. The reduction in air pressure just referred to is on the order of from 10 to 14 p.s.i. below atmospheric pressure.

When all of the metal within the mold cavity has frozen and solidification begins in the gate leading to the mold cavity, the upper portion of the mold with the casting therein is raised from the bottom portion and the cast body is ejected from the raised portion of the mold. The size of the protuberance extending into the gate is determined by the time which is permitted to elapse before the mold is raised. By careful timing only a very small protuberance is developed which can be

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easily removed, or if small enough, it may be disregarded. The reduced air pressure at the bottom of the casting is, of course, terminated when the upper mold portion and casting are raised and the vacuum at the top of the mold cavity is ended when the casting is to be ejected. Such ejection may be conveniently effected by pneumatic means, as by applying compressed air to the top of the mold cavity, or by mechanical means, as with ejector pins. Continuation of the reduced air pressure as the upper mold portion and casting are being raised is generally desirable to retain the casting in place.

A machine for producing castings at a high rate of output includes a two-part mold and the mechanism for operating it in conjunction with means for controlling the air pressure within the mold cavity. The mold, made of any suitable heat resistant material such as a ferrous alloy, consists of an upper or top portion which defines the top and side walls of the mold cavity, and a bottom portion composed of a plate which forms the bottom of said cavity. The mold is therefore parted in a horizontal direction, the parting line preferably being at the surface of the bottom plate. At least one gate opening is provided in the plate for passage of molten metal into the mold cavity. Where a hollow casting is to be produced, it is desirable to employ two or more symmetrically disposed gates in order to provide rapid and equal flow of metal into all parts of the mold cavity. The diameter or cross sectional area of the gates must be large enough to permit the flow of metal therethrough, prevent undue freezing of metal therein and at the same time not so large as to permit the formation of protuberances which are difficult to remove.

The top or upper portion of the mold is movable in a vertical direction, while the bottom portion is maintained in a stationary position. This movement of the upper portion of the mold body is essential to operation of the mold to permit ejection of the casting. In the form of the machine for producing hollow castings a core member is provided which is movable with respect to the top and side walls of the mold. Such relative movement is necessary prior to ejection of the casting from the mold.

The evacuation of air from the mold cavity and admission of air thereto is effected through ducts leading to vents at the top and bottom of the cavity which are so narrow that the molten metal will not enter them even though air is withdrawn through them. A very satisfactory arrangement is that of locating the vents at the junctions or corners where the side wall of the mold joins the top and bottom members. The vents may be in the form of separate openings or a continuous opening around the periphery of the mold cavity. By providing vents at the corners, especially at the top of the mold cavity, the cavity is properly filled with metal and any voids or other imperfections associated with poor filling are avoided.

Associated with the mold are means for supporting it on a framework and for moving the upper portion in sequence with respect to the introduction of molten metal and ejection of the casting from the mold. Suitable pneumatically or hydraulically operated cylinders mounted on the frame offer convenient and efficient power means.

A transfer device for receiving the castings ejected from the mold and transporting them to a discharge station also forms a part of the casting machine inasmuch as it must function in sequential relationship to the mold operations.

Specific forms of the apparatus described above are illustrated in the accompanying figures, Figs. 1 and 2 showing a machine for making solid cylindrical castings while Figs. 3 to 6 set forth a machine for casting hollow cylindrical bodies. A plan view of the first mentioned machine is to be seen in Fig. 1 where the casting unit is suspended above a metal holding pot and a device at

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one side of the unit for receiving and transferring the cast slugs ejected from the mold. The casting unit is suspended over a melting pot from a cap plate 14 resting upon ring member 12 which in turn is carried on channel frame members 10. The stationary bottom portion of the mold is bolted to the lower ends of four symmetrically disposed columns 16 which are attached by bolts at their upper ends to the cap plate 14. The upper or movable part of the mold assembly is supported from a crosshead 54 which slides on columns 16 and is guided by sleeves 58 fixed to the crosshead. Posts having caps 74 are rigidly attached to mold top plate 66 and pass through the crosshead, connection thereto being made by compression springs as seen in Fig. 2. Movement of the crosshead is effected by air or hydraulic cylinder 18 mounted on the cap plate 14. The stationary or lower portion of the mold assembly is located within a circular opening in the metal pot cover 38, as more clearly seen in Fig. 2.

The device for receiving and transferring cast slugs may be integrally connected to the casting unit or it may be independently mounted to permit movement into or out of operating position. The device consists of a rectangular bed frame 22 carrying a sliding frame 24 with tray 26 positioned thereon and means for moving the frame and tray into position for receiving the cast slug dropped from the mold and retracting it from the receiving position. A convenient means for moving frame 24 and tray 26 consists of an air cylinder 32 mounted on auxiliary frame 30 which is rigidly attached to the main frame 22 and operatively connected to the sliding frame 24 by rod 34. A cast slug 28 is to be seen resting upon tray 26 in retracted position.

A side elevation of the casting machine which shows more details and the structural relationship of the various parts to each other is to be seen in Fig. 2 which is taken on line II—II of Fig. 1. The stationary bottom portion of the mold consists of a dish-shaped member, preferably made in two parts, a bottom plate 44 with a gate opening 46 therein and an L-shaped upper part composed of a vertical wall section 48 and an outwardly extending flange 50 for attachment to columns 16. The two parts may be mechanically joined together in conventional manner, or they may be welded if the structural material permits. Although the dish-shaped member can be of unitary construction, it is frequently desirable to make it in two parts so that the bottom plate can be replaced when necessary. As a matter of practice it is usually advantageous to coat at least the under side of the bottom plate with a conventional refractory coating to minimize attack by the molten metal. Generally, ferrous metals are suitable for construction of the mold and mold parts.

The upper or movable portion of the mold, suspended from the crosshead 54, is composed of two parts, a vertical wall portion 64 and a top member 66 rigidly joined thereto by mechanical means. Posts 68, for supporting the upper mold portion from the crosshead 54, may be screwed into top member 66, or they may be attached by these means to a base 70 which in turn is joined to 66. The posts 68 are freely movable in openings provided in the crosshead for this purpose. A resilient connection with the crosshead is provided by a pair of compression springs 72 encircling the posts, one being located above the crosshead plate and the other below the plate. The upper spring is held in place between cap 74 on posts 68 and the crosshead, the spring preferably being seated in a slight recess in the plate to prevent displacement. The lower spring is similarly positioned between the plate 54 and the post base 70. The springs serve to establish and maintain the alignment and contact necessary between the upper and lower portions of the mold which is necessary to produce a tight seal when they are pressed together and to absorb the shock of contact between the moving and stationary mold elements as well as any shock

resulting from abrupt movement of the crosshead by the power cylinder 18.

The crosshead is maintained in proper alignment by means of guide sleeves 58 sliding on columns 16 having reduced threaded extensions 60 for receiving lock nuts 62. The movement of the crosshead is effected through connecting rod 52 which joins the crosshead to the plunger in power cylinder 18.

With respect to the cooling of the side and top portions of the mold, spirally arranged internal tubes or channels 76 may be provided. Alternatively, a water chamber or jacket may be employed which extends over substantially the same wall area. To provide such internal water passages it is usually desirable to make the mold wall or top in two parts, to machine the channels or recesses therein and join the two parts by any suitable means. The water passageways, of course, must be adequate to provide for rapid dissipation of heat from the mold and consequently should be large enough to prevent any clogging or obstruction from any dirt or suspended particles that may be carried by the water. The upper mold parts may be made of any conventional ferrous metal or other material which will withstand the repeated contact with molten metal.

The air duct system for evacuating the mold cavity 67 and admitting air thereto consists of a portion which serves the top of the cavity and the other which serves the bottom thereof. Duct 78, which is confined to the top mold member, extends inwardly from the outer edge of the member to an annular channel or groove 80 which encircles the mold cavity and is in close proximity to the cavity. The channel or groove 80 may be machined or otherwise provided in the top surface of vertical mold section 64 before the mold parts are assembled. Communication between the channel 80 and mold cavity 67 is provided by a narrow circumferential vent 82, which is of such a small width that molten metal does not enter it under the reduced pressure conditions prevailing in the mold cavity during the filling thereof with molten metal. Provision of a vent around the entire circumference of the mold cavity has been found to be very effective for withdrawing air and promoting a quick and complete filling of the cavity with molten metal. The vent also provides for the quick and effective application of compressed air to the top of the casting to eject it from the mold. If ejector pins are employed a vent may be provided around them and dispense with the upper duct system. The other portion of the duct system consists of a duct 84 in the top mold member which registers with a vertical passageway 86 in the side mold member. The duct 86 leads into an annular channel or groove 88 which in turn communicates with the mold cavity through narrow vent 90. A rim or ridge 92 is provided at the outside edge of the bottom surface of side member 64 to establish a seal with bottom plate 44 and prevent ingress of air from the surrounding atmosphere. Conventional fittings 94 and hose are provided to connect the ducts with regulating valves and air line to the pumps not shown.

In operating position the bottom plate 44 is partially submerged below the surface 42 of the body of molten metal 40 in holding pot 20. As a result of the submergence, molten metal rises in gate 46 almost to the top of the plate 44.

The cast slug transfer device is mounted at an elevation such that the movable frame 24 with tray 26 can be advanced to a position to receive slugs ejected from the mold when in the fully raised position. The transfer device, of course, must be located to pass between columns 16 and to clear the top of the dish-shaped bottom member.

A modification of the foregoing machine, which is adapted to produce hollow castings, is shown in Figs. 3 to 6. From the plan view appearing in Fig. 3 it will be apparent that the casting unit is supported in the same manner as the one described above and that the same type of transfer device is used to receive and remove cast-

ings dropped from the mold. It is to be noted, however, that only three symmetrically spaced columns 16 are employed to support the unit from cap plate 14. The other supporting columns and posts, 134, 68, 144 and 156 are aligned with the main columns 16. Mounted on the cap plate 14 is a power cylinder 18 which raises and lowers the entire upper mold assembly including the core elements. Below the main cap plate 14 is a second one, 132 with which the power cylinder is connected and which supports the upper mold assembly. A third cap plate 148, smaller than 132, supports the core actuating power cylinder, not seen in this view, and below it is plate 154 attached to the movable core member.

Details of construction and the relationship of the various parts of the machine to each other are illustrated in Figs. 4, 5 and 6. In the sectional view appearing in Fig. 4, it will be seen that the stationary and lower portion of the mold consists of a dish-shaped member as in the machine described hereinabove. The dish is preferably made in two parts, a bottom plate 44 and an L-shaped upper part, the horizontal flange portion 50 serving as the base for attachment of the supporting columns 16. In the production of hollow castings it is advisable to provide a plurality of gates to obtain rapid and uniform filling of the mold cavity. In the present instance four symmetrically spaced gates 46 are located in the bottom plate 44, only two of the gates being seen in the figure.

The upper, or movable portion of the mold, which cooperates with the bottom plate to form the mold cavity 99, is composed of side wall member 64, top member 98 and liquid cooled core member 100. The side wall member 64 may be conveniently attached to top member 98 by a long shank bolt, as shown, or the two parts may be joined in other mechanical manner. The mold top member 98 is firmly attached to cylindrical core guide 142 by any convenient means such as a long through bolt. To maintain the proper alignment of the mold parts with the guide 142, a collar 102 is provided which encircles the mold top 98 and bears against both the guide and mold side wall. The collar 102 need not be rigidly attached, but should be snugly fitted to maintain the desired alignment.

The core assembly consists of a slightly tapered (less than 1°) liquid cooled tip 100 which is an extension of the main core body 122 that moves in guide 142. The upward movement of the core is limited by a stop 146 in the shape of a ring which is secured to the top of the guide cylinder 142 by the same through bolt which connects the guide to the top mold member 98. It will be appreciated that the stop may be attached in other manners and that the stop may assume other forms than that of a ring. The stop 146 is located only a short distance above the core member in its lowermost position since because of the taper of the core it is only necessary to raise the core less than the height of the casting to separate it from the casting preparatory to ejecting the cast body from the mold. Three symmetrically disposed posts 144, rigidly attached at their lower ends to ring 146, or the guide 142, carry the cap plate 148 on which power cylinder 150 is mounted. The power cylinder, which may be pneumatically or hydraulically operated, raises and lowers the core by means of rod 152 attached to the plunger and bolted to plate 154. The plate 154, spaced from the core body 122, is connected thereto by posts or legs 156 rigidly attached to both the plate and core body. The relative position of the supporting members with respect to the crosshead and core assembly are clearly seen in the sectional view in Fig. 5, also the spacing of the mold from the crosshead.

The core tip 100 is cooled by a liquid, preferably water, circulated in chamber 128 which is divided into

substantially two portions by baffle 126 that extends across the chamber and almost to the bottom thereof. The baffle, as shown in Fig. 6, is an extension of plug 158 fitted in the top of the bore forming chamber 128. The water or other coolant is admitted to the chamber through tube 130 and duct 124 and is discharged through a similar duct and tube. The tubes 130 are arranged to pass through the cap plate 154 in order to facilitate making connections with a source of water.

The whole upper mold assembly just described is suspended from cap plate 132 by three symmetrically spaced columns 134 bolted at their lower ends to crosshead 136. As previously stated the movement of the crosshead 136 and assembly supported therefrom is effected by power cylinder 18 through connecting rod 52 attached to cap plate 132. The crosshead is guided on columns 16 by sleeves 58 as in the machine described above. A central opening 138 is provided in the crosshead to accommodate the upper mold assembly, the latter being resiliently connected to the crosshead through compression springs 72 which surround supporting posts 68. The posts 68 are mechanically attached to the circular flange 140 which is joined to the guide 142. The upper compression spring is positioned between the post cap 74 and the crosshead while the lower spring is mounted between the flange 140 and the crosshead.

The admission and evacuation of air to the top of the mold cavity is effected through duct 104, annular groove 106 and vents 107 and 108. In the production of hollow castings it is essential that provision be made for withdrawal and admission of air adjacent the core as well as the outer mold wall. To this end a small recess 109 is provided in the main core body 122 which registers with duct 104 and terminates at vent 107 so that when assembled with top plate 98 there is a passageway from duct 104 to the vent 107. Both vents 107 and 108 are situated at the upper corners of the mold cavity and are of such a narrow width that the molten metal does not enter them as the mold cavity is filled. The other duct 110 communicates with the bottom of the mold cavity through a vertical passageway 112 in mold wall 64. The passageway 112 terminates in annular groove 114 which is in communication with the mold cavity through vent 116. A slight rim 118 is provided at the outer edge of the side wall member 64 to effect a seal against the admission of air to the mold cavity during the period of evacuation. Fittings 120 are threaded into ducts 104 and 110 and the tubes associated therewith provide a connection to control valves and the air and vacuum pumps not shown.

The sectional view seen in Fig. 6 shows the water passages to the core chamber 128, the mold cavity around the core and the air passageways leading to the mold cavity.

A cast slug transfer device of the same character as that shown in Fig. 2 may be employed to receive and remove slugs ejected from the mold.

To conduct the process and operate the machines referred to above, the holding pot 20 is filled with molten metal to the desired level 42 which is preferably maintained throughout the series of casting operations. This level may be maintained in known manner such as by the manual ladling of a small quantity of metal at intervals, by gradually pouring metal from a holding ladle or by an automatic float-control arrangement. The casting machine may be lowered into place on the supporting framework over the holding pot, or the latter may be elevated to the desired level. In any event, the bottom plate 44 of the mold must be partially submerged in the metal bath 40 but care must be exercised to avoid immersing it to a depth such that the molten metal runs into the mold cavity under hydrostatic pressure. To facilitate commencement of casting it is advisable to pre-heat the bottom plate before submerging it in the metal bath but, of course, the heating may be effected by sub-

merging the cold plate in the metal bath. The plate, however, should attain a temperature of between about 900 and 1300° F. to produce satisfactory castings. Also, the circulation of coolant is started in the top and side wall members of the mold and core, if one is employed, before casting operations are commenced. The upper mold portion, which is initially at room temperature, becomes heated as the casting operations progress but the temperature should not exceed 400° F. Once the mold bottom has attained the desired operating temperature and the proper temperature differential of from 500 to 1200° F. has been established between the upper portion of the mold and the bottom plate, the casting operations can start.

The first step of the casting cycle comprises withdrawing of the air through all the ducts either before or just after the upper mold portion has been seated upon the bottom plate. To form the mold cavity, the top portion of the mold, including the core member, is lowered to establish contact with the bottom plate and enough pressure exerted on the top portion through the compression springs to prevent any substantial leakage of air into the mold cavity. The sealing of the mold cavity is effected by contact of rims 92 or 118 with the bottom plate 44. The air pressure within the mold cavity is reduced from 0.1 to 1.5 p.s.i. below atmospheric pressure, the particular value chosen in any instance being determined by the height to which the molten metal must be raised.

Upon establishment of the mold cavity and reduction of the air pressure therein molten metal immediately rises within the cavity under the influence of atmospheric pressure until the cavity is filled. As mentioned hereinabove, the rate of withdrawal of the air may be gradually increased to a predetermined maximum value as the filling of the mold progresses. Such withdrawal of air and control of the rate of extraction is effected through suitable valves and pumps not shown.

Upon completion of the filling of the mold cavity, and in some cases before all of the metal has frozen therein, a higher vacuum can be established at the top of the cavity while retaining substantially the same degree of evacuation at the bottom of the cavity which was employed during the filling operation. The higher vacuum should be on the order of 10 to 14 p.s.i. below atmospheric pressure. The use of a higher vacuum at the top of the mold cavity is desirable in the production of solid castings since it aids in holding the casting in place in the upper mold portion when it is lifted from the bottom plate and it helps maintain a closer contact between the casting and mold top. In making hollow castings the shrinkage of the solidifying metal around the core serves to hold the casting securely in the upper mold body and the overall chill rate is so high that early application of the high vacuum is not required to shorten the casting cycle. Hence, in making cored castings, there is generally no need for employing a higher vacuum. Where a higher vacuum is employed, it represents a second step in the casting cycle.

The next step consists in separating the top portion of the mold from the bottom plate. This may be accomplished while a high vacuum is still maintained at the top of the mold cavity and while air is being withdrawn from the bottom of the mold cavity. If desired, withdrawal of air from the bottom of the mold cavity may be terminated but this is not necessary as the reduced air pressure is too small to interfere with mechanical separation of the upper and lower portions of the mold. The upper portion of the mold with casting therein is elevated to a sufficient height by operation of power cylinder 18 to permit advancement of the sliding frame and tray to a receiving position.

In the last step of the cycle after the tray 26 has been moved into receiving position, the withdrawal of air is terminated at the top of the mold cavity and a positive air pressure is substituted which serves to eject the cast-

ing from the mold. It is to be understood that other means of ejecting the casting may be employed such as mechanical ejector pins.

Upon retraction of the tray 26 with casting 28 or 160 thereon the upper portion of the mold is ready for re-seating on the bottom plate and for repetition of the cycle.

In the production of hollow castings the last step must be modified to include movement of the core member 100 before ejection occurs. As mentioned above it is only necessary to raise this member a short distance, less than the total height of the mold cavity, in order to release it from the casting. The core may be lifted before the upper mold assembly is raised or after such movement has begun. However, it is usually desirable to wait until the mold has been elevated before releasing the core and thus take advantage of any adherence of the casting to the core. Ejection can be effected by compressed air as described above or mechanical means may be used.

The cast bodies produced by our process and in our machine possess a very smooth surface free from shrinks and voids. The freezing occurs at a sufficiently rapid rate to produce a fine metallurgical structure. The fillets formed at the corners eliminate any sharp edges. Only small stems or protuberances remain where the casting was gated and these can be easily removed or even disregarded in some cases.

It will be appreciated that although the production of circular castings has been described, other shapes can be made such as oval, polygonal or rectangular. It is also possible to make hollow castings having different interior and exterior contours. In any case to secure high production rates it is desirable to make simple shapes with straight or tapering side walls that facilitate ejection of the casting from the mold. In making castings of non-circular shape it may be necessary to rearrange the cooling means and change the location of the gates in the bottom plate but such alterations are within the skill of those familiar with the production of chill castings.

The rate of producing castings can be considerably increased if a casting machine is enlarged to permit the simultaneous casting of a number of slugs. An upper mold element can be made which includes a plurality of mold cavities and the bottom plate can be made with any number of gate openings to register with the mold cavities.

Having thus described our invention and certain embodiments thereof, we claim:

1. The method of making a light metal chill casting comprising providing a chill mold having at least one gate opening in the bottom thereof, establishing and continuously maintaining the mold bottom at a relatively high temperature and partially immersed in a body of molten light metal, the mold bottom being so positioned with reference to the body of molten metal that the underside of the mold bottom is submerged but the mold cavity is at all times above the top surface of the molten metal and no metal flows into the mold under hydrostatic pressure, artificially cooling the upper portion of the mold whereby a temperature differential is maintained between said upper portion and the bottom, partially evacuating the mold cavity while maintaining the external walls of the upper portion of said mold under atmospheric pressure and filling said mold cavity from the bottom with molten metal drawn from said body of molten metal under the influence of the external atmospheric pressure, progressively chilling and solidifying the metal from the top and sides of the mold cavity toward the gate openings and finally removing the casting from the mold.

2. The method of making a light metal chill casting comprising providing a chill mold having at least one

gate opening in the bottom thereof, establishing and continuously maintaining the mold bottom at a temperature between 900 and 1300° F. and partially immersed in a body of molten light metal, the mold bottom being so positioned with reference to the body of molten metal that the mold cavity is at all times above the top surface of the molten metal and no metal flows into the cavity under hydrostatic pressure, artificially cooling the upper portion of the mold whereby a temperature differential of 500 to 1200° F. is maintained between the said upper mold portion and the mold bottom, partially evacuating the mold cavity and filling it from the bottom with molten metal drawn from said body of molten metal under the influence of the external atmospheric pressure, progressively chilling and solidifying the metal from the top and sides of the mold cavity toward the gate openings and finally removing the casting from the mold.

3. The method of making a light metal chill casting comprising providing a chill mold having at least one gate opening in the bottom thereof, establishing and continuously maintaining the mold bottom at a temperature between 900 and 1300° F. and partially immersed in a body of molten light metal, the mold bottom being so positioned with reference to the body of molten metal that the mold cavity is at all times above the top surface of the molten metal and no metal flows into the cavity under hydrostatic pressure, artificially cooling the upper portion of the mold whereby the temperature is maintained between 80 and 400° F., reducing the air pressure within the mold cavity to between 0.1 and 1.5 p.s.i. below atmospheric pressure, filling the mold cavity from the bottom with molten metal drawn from said body of molten metal under the influence of the external atmospheric pressure, progressively chilling and solidifying the metal from the top and sides of the mold cavity toward the gate openings and finally removing the casting from the mold.

4. The method according to claim 3 wherein the air pressure, within the mold cavity is gradually reduced to a predetermined minimum between 0.1 and 1.5 p.s.i. below atmospheric pressure as the mold is being filled.

5. The method of making a light metal chill casting comprising providing a horizontally parted chill mold having at least one gate opening in the bottom of the lower portion, establishing and continuously maintaining the mold bottom at a temperature between 900 and 1300° F. and partially immersed in a body of molten light metal, the mold bottom being so positioned with reference to the body of molten metal that the mold cavity is at all times above the top surface of the molten metal and no metal flows into the cavity under hydrostatic pressure, artificially cooling the upper portion of the mold whereby the temperature is maintained between 80 and 400° F., reducing the air pressure within the mold cavity to between 0.1 and 1.5 p.s.i. below atmospheric pressure, filling the mold cavity from the bottom with molten metal drawn from said body of molten metal under the influence of the external atmospheric pressure, progressively chilling and solidifying the metal from the top and sides of the mold cavity toward the gate openings while simultaneously further reducing the air pressure in the upper portion of the mold cavity, raising the upper portion of the mold with the casting therein above the lower portion and ejecting the casting from said upper portion.

6. The method of making a light metal chill casting comprising providing a horizontally parted chill mold having at least one gate opening in the bottom of the lower portion, establishing and continuously maintaining the mold bottom at a temperature between 900 and 1300° F. and partially immersed in a body of molten light metal, the mold bottom being so positioned with reference to the body of molten metal that the mold cavity is at all times above the top surface of the molten metal and no

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metal flows into the cavity under hydrostatic pressure, artificially cooling the upper portion of the mold whereby the temperature is maintained between 80 and 400° F., partially evacuating the mold cavity and filling it from the bottom with molten metal drawn from said body of molten metal under the influence of the external atmospheric pressure, progressively chilling and solidifying the metal from the top and sides of the mold cavity toward the gate openings, raising the upper portion of the mold with the casting therein, terminating the evacuation at the top of the mold cavity and substituting a positive air pressure whereby the casting is ejected from the mold.

7. A machine for making chill castings wherein the lower portion of the mold is maintained in continuous contact with a body of molten metal and the mold is filled from the bottom, said machine comprising a main frame, a mold unit supported from said frame, said mold unit including a horizontally divided mold the upper portion of which is movable and composed of top and side wall members that form, respectively, the top and side walls of the mold cavity, and the lower portion which is stationary and composed of a plate member rigidly attached to the main frame that forms the bottom of the mold cavity, said bottom plate member having at least one relatively small gate opening therein for passage of molten metal into said mold cavity, the length of said gate being defined by said bottom plate member, cooling means associated with said upper portion to maintain it at a lower temperature than the bottom plate member, said upper portion also being provided with separate upper and lower duct and vent systems for withdrawal and admission of air to the mold cavity, said upper system consisting of a duct terminating in at least one vent at the top of the mold cavity and said lower system consisting of a duct terminating in a vent established by seating of the upper mold portion on the bottom plate, each duct and vent system being connected to means for withdrawing or introducing air to the mold cavity, means connected to said upper mold portion for raising and lowering the same and establishing a sealing contact between said upper mold portion and the bottom plate member whereby leakage of air from the external atmosphere into the mold cavity is substantially prevented and a container below said mold adapted to hold the molten metal supplied to the mold.

8. A machine for making chill castings wherein the lower portion of the mold is maintained in continuous contact with a body of molten metal and the mold is filled from the bottom, said machine comprising a main frame, a mold unit supported from said frame, said mold unit including a horizontally divided mold the upper portion of which is movable and composed of top and side wall members that form, respectively, the top and side walls of the mold cavity, the side wall members consisting of a fixed outer member and the inner wall consisting of a movable core member, the lower portion of said mold being stationary and composed of a plate member rigidly attached to the main frame that forms the bottom of the mold cavity, said bottom plate member having at least one relatively small gate opening therein for passage of molten metal into the mold cavity, the length of said gate being defined by said bottom plate member, cooling means associated with said upper mold portion, including the core, to maintain it at a lower temperature than the bottom plate member, said upper portion also being provided with separate upper and lower duct and vent systems for the withdrawal and admission of air to the mold cavity, said upper system consisting of a duct terminating in vents at the top of the mold cavity and said lower system consisting of a duct terminating in a vent established by seating the outer fixed side wall mold member on the bottom plate member, each duct and vent system being connected to means for withdrawing and introducing air to the mold cavity, means connected to said upper mold portion for raising and lowering the same and means

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associated with said core to raise and lower it, said means for raising and lowering the upper mold portion also being capable of establishing sealing contact between said upper portion and the bottom plate member whereby leakage of air from the external atmosphere into the mold cavity is prevented, and a container below said mold adapted to hold the molten metal supplied to the mold.

9. A machine for making solid cylindrically shaped castings of light metal wherein the lower portion of the mold is maintained in continuous contact with a body of molten metal and the mold is filled from the bottom, said machine comprising a main frame, a mold unit supported from said frame, said mold unit including a horizontally divided mold the upper portion of which is movable and consists of cylindrical side walls and a flat top joined thereto which form the side walls and top of the mold cavity, the lower portion of the mold consisting of a flat plate member rigidly attached to the main frame which in cooperation with the upper mold portion forms the bottom of the mold cavity, said bottom plate member having at least one relatively small gate opening therein for passage of molten metal into the mold cavity, the length of said gate being defined by said bottom plate member, a circumferential rim at the base of the circular side wall member which establishes sealing engagement with the bottom plate member under pressure applied to the upper mold portion, liquid coolant passageways associated with said side and top members of the upper mold portion whereby the temperature of said upper portion is maintained below that of the bottom plate member, said upper portion also being provided with separate upper and lower duct and vent systems for withdrawal and admission of air to the mold cavity, said upper system consisting of a duct communicating with a circumferential vent at the junction of the top and side wall members of the upper mold portion, and the lower system consisting of a duct communicating with an annular groove in the base of the mold side wall member and said groove further communicating with the mold cavity through a circumferential vent at the junction of the side wall member and the bottom plate member when the upper mold portion is seated on the bottom plate, each duct and vent system being connected to means for withdrawing and introducing air to the mold cavity, fluid power means connected to said upper mold portion for raising and lowering the same and establishing a sealing contact between the circumferential rim at the base of the side wall member and the bottom plate member whereby leakage of air from the external atmosphere into the mold cavity is substantially prevented, and a container below said mold adapted to hold the molten metal supplied to the mold.

10. A machine for making hollow cylindrically shaped castings of light metal wherein the lower portion of the mold is maintained in continuous contact with a body of molten metal and the mold is filled from the bottom, said machine comprising a main frame, a mold unit supported from said frame, said mold unit including a horizontally divided mold the upper portion of which is movable and composed of an outer cylindrical side wall member, flat top member joined to said side wall and a cylindrically shaped movable central core member, and the lower portion of said mold consisting of a stationary flat plate member rigidly attached to the main frame having a plurality of relatively small gate openings therein for passage of molten metal into the mold cavity, the length of said gates being defined by the thickness of said stationary flat plate member, liquid coolant passageways associated with said outer cylindrical side wall member and said core member whereby they are maintained at a temperature below that of the bottom plate member, said upper portion of the mold also being provided with separate upper and lower duct and vent systems for the withdrawal and admission of air to the mold cavity, said upper system consisting of a duct terminating in a circumferential vent

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at the junction of the side wall with the mold top member and in a second vent at the junction of the top member with the central core member, the lower duct and vent system consisting of a duct terminating in an annular groove in the base of the side wall and said groove communicating with the mold cavity through a circumferential vent at the junction of the side wall member with the bottom plate when the upper mold portion is seated on the bottom plate member, each duct and vent system being connected to means for withdrawing and introducing air to the mold cavity, fluid power means connected to said upper mold portion for raising and lowering it and establishing a sealing contact between said side wall and bottom plate member whereby leakage of air from the external atmosphere into the mold cavity is substantially prevented, a second fluid power means connected to said central core member for raising and lowering it, and a container below said mold adapted to hold molten metal supplied to the mold.

11. A machine for making chill castings in combination with a casting transfer device wherein the lower portion of the mold in the casting machine is maintained in continuous contact with a body of molten metal and the mold is filled from the bottom, said machine comprising a main frame, a mold unit supported from said frame, said mold unit including a horizontally divided mold the upper portion of which is movable and composed of top and side wall members that form, respectively, the top and side walls of the mold cavity, and the lower portion which is stationary and composed of a plate member rigidly attached to the main frame that forms the bottom of the mold cavity, said bottom plate member having at least one relatively small gate opening therein for passage of molten metal into said mold cavity, the length of said gate being defined by said bottom plate member, cooling means associated with the upper mold portion to maintain it at a lower temperature than the bottom plate member, said upper portion also being provided with separate upper and lower duct and vent systems for withdrawal and admission of air to the mold cavity, said upper system consisting of a duct terminating in at least one vent at the top of the mold cavity and said lower system consisting of a duct terminating in a vent established by seating of the upper mold portion on the

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bottom plate member, each duct and vent system being connected to means for withdrawing or introducing air to the mold cavity, means connected with said upper mold portion for raising and lowering the same and establishing a sealing contact between said upper portion and the bottom plate member whereby leakage of air from the external atmosphere into the mold cavity is substantially prevented, and a casting transfer device positioned at one side of the casting machine and operatively associated therewith, said transfer device comprising a frame and a reciprocable tray mounted thereon and means for advancing and retracting said tray, said tray being located at an elevation with respect to the mold unit such that in advanced position it comes between the upper and lower mold portions when the upper portion is in raised position to receive the casting ejected from the raised upper mold portion.

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