April 16, 1963 A. P. FEDERMAN 3,085,302

VACUUM DIE CASTING METHOD AND APPARATUS

Filed Jan. 19, 1956 4 Sheets-Sheet 1

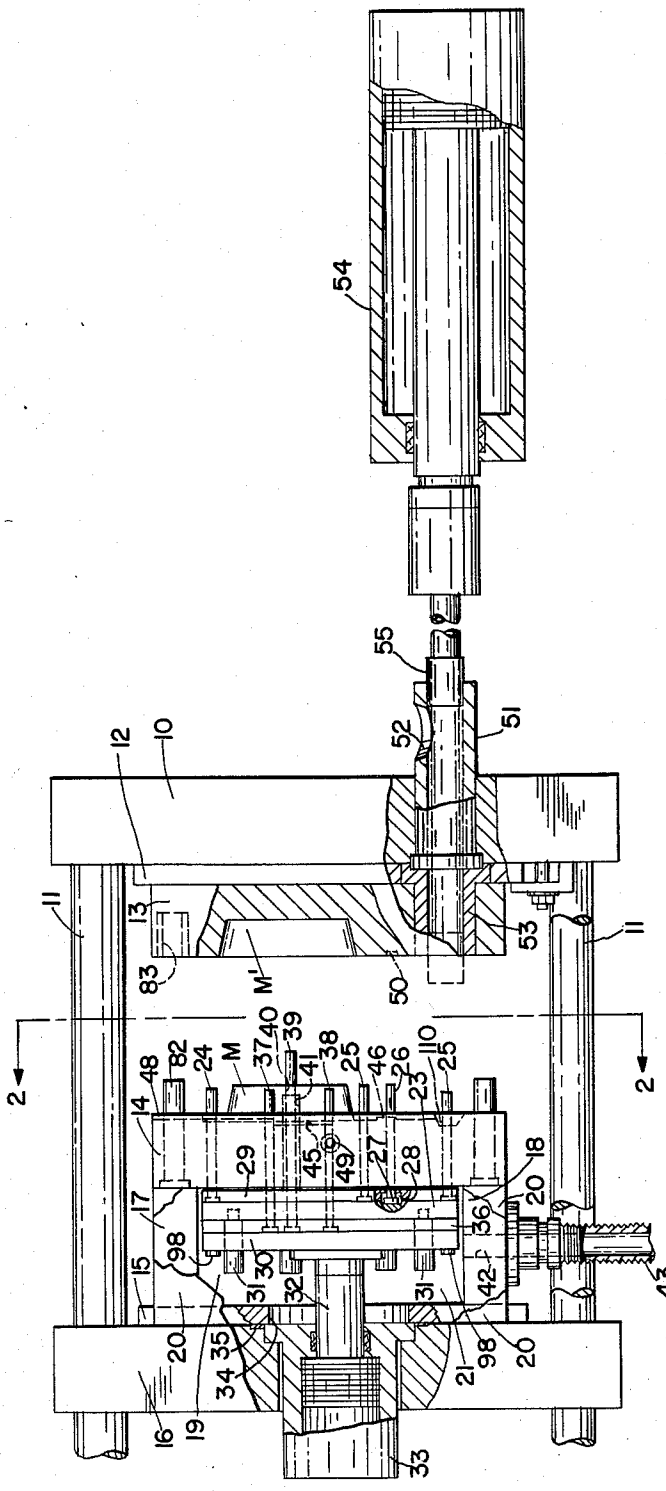

Fig. 1

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VACUUM DIE CASTING METHOD AND APPARATUS

Filed Jan. 19, 1956 4 Sheets-Sheet 2

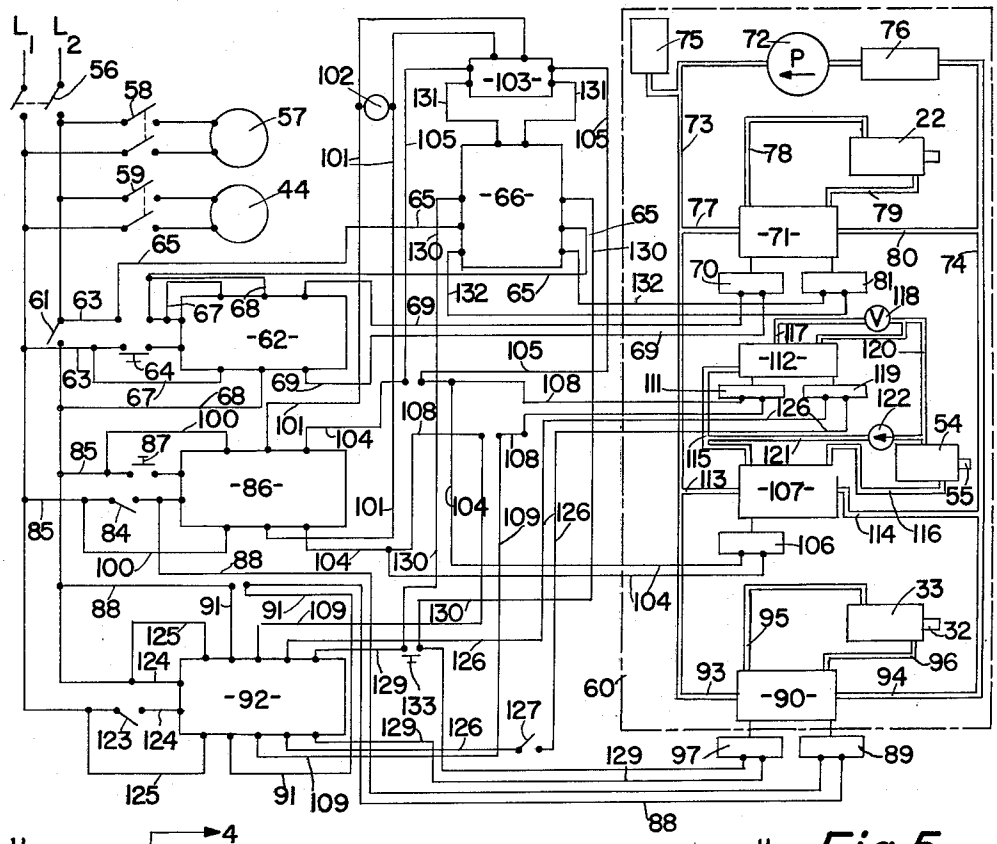

Fig. 5

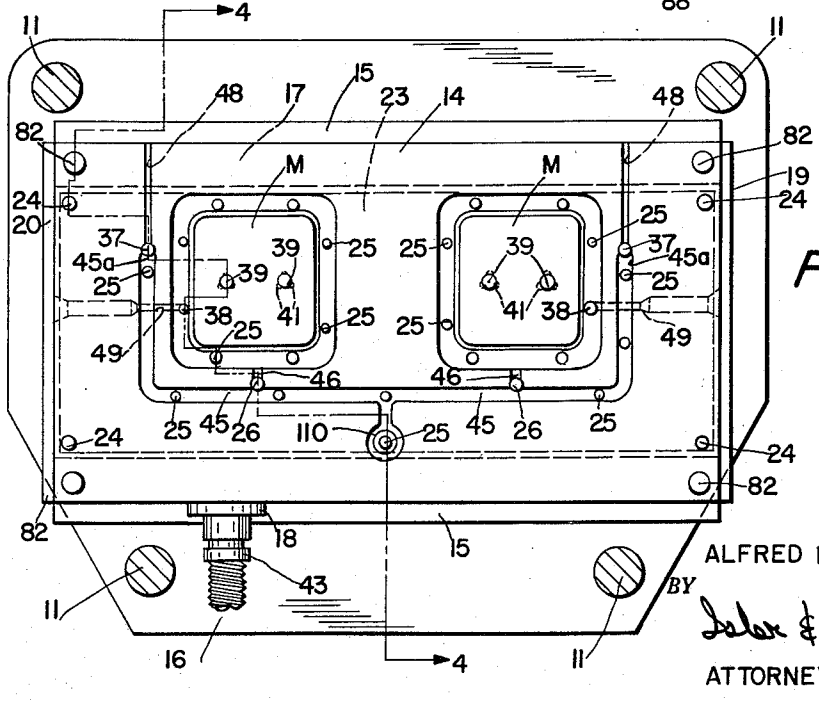

Fig. 2

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VACUUM DIE CASTING METHOD AND APPARATUS

Filed Jan. 19, 1956 4 Sheets-Sheet 3

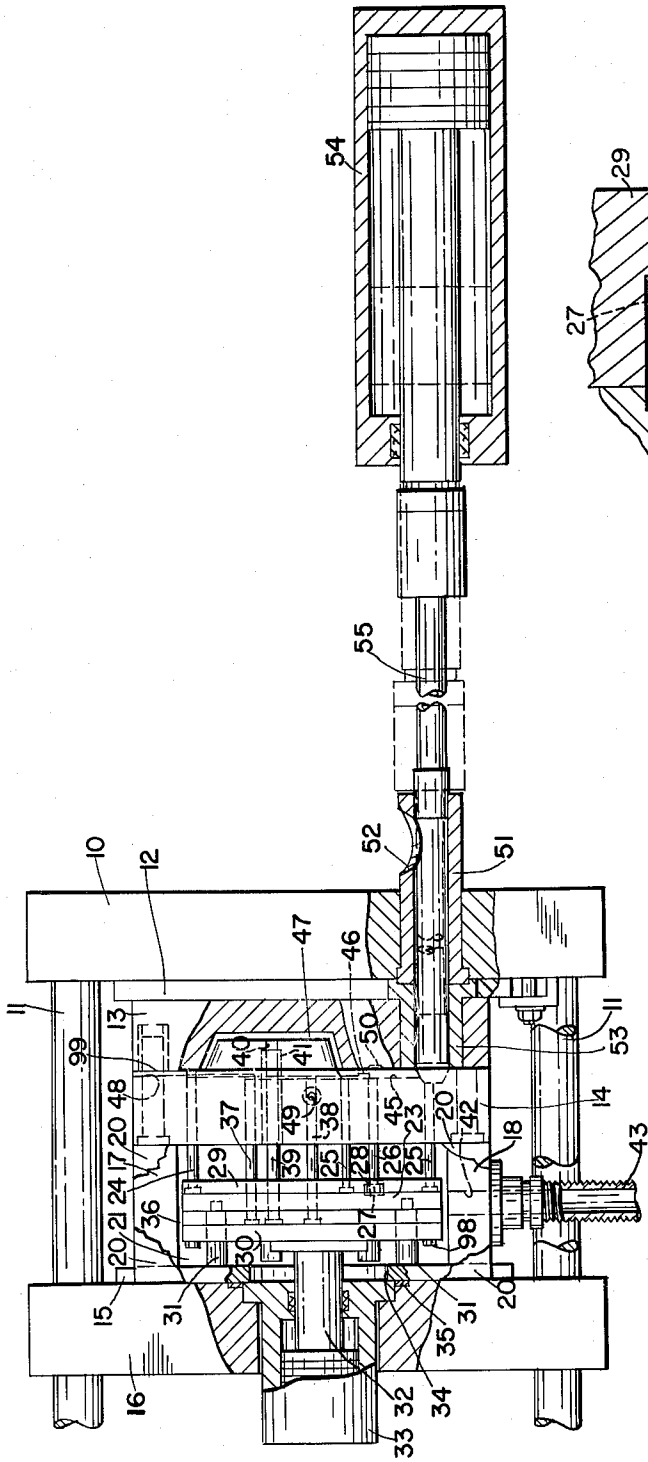

Fig. 3

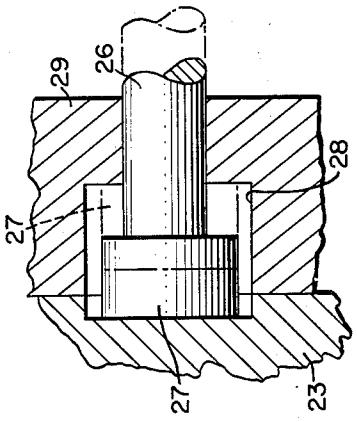

Fig. 3a

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VACUUM DIE CASTING METHOD AND APPARATUS

Filed Jan. 19, 1956 4 Sheets-Sheet 4

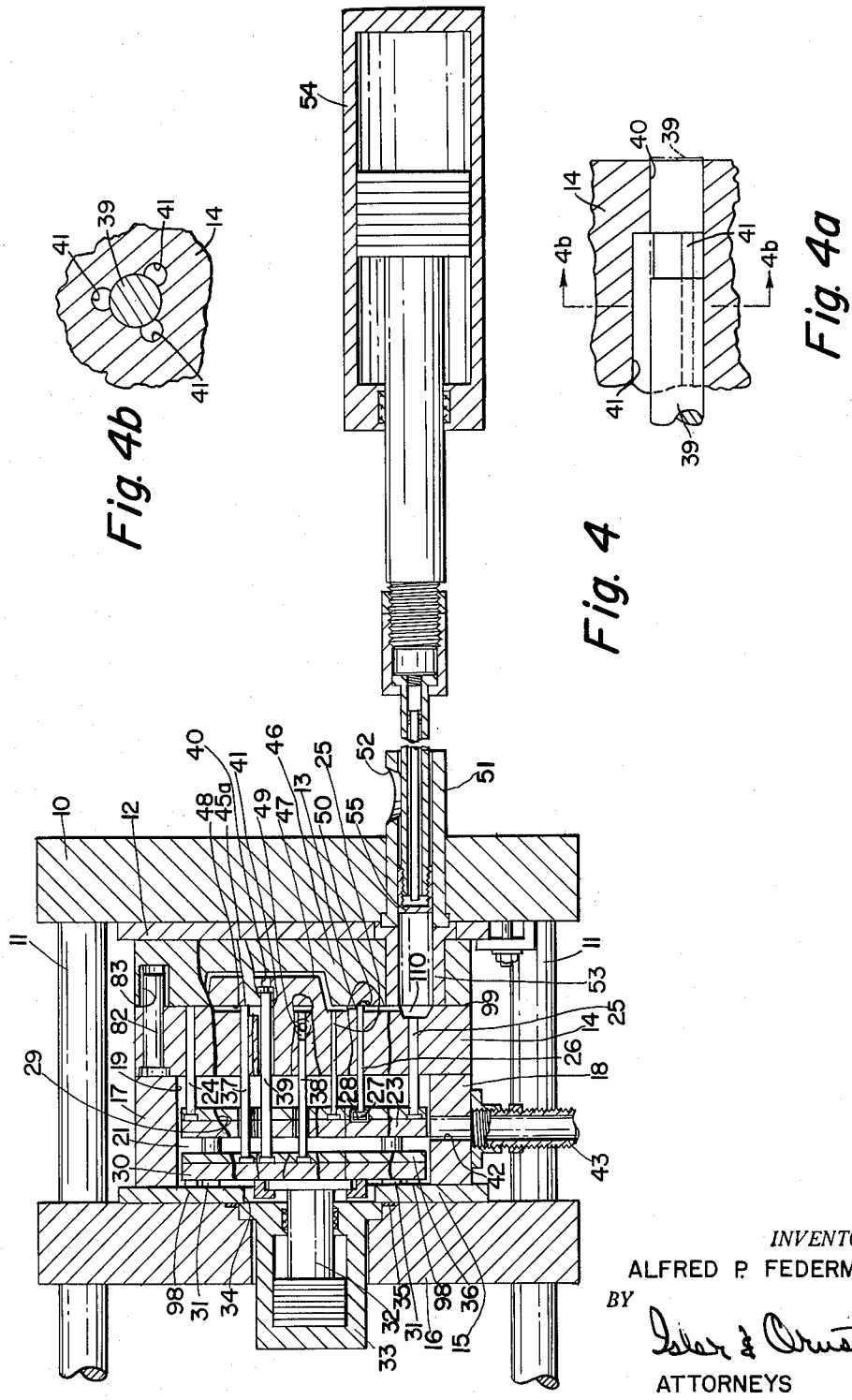

Fig. 4

Fig. 4b

Fig. 4a

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3,085,302

VACUUM DIE CASTING METHOD AND APPARATUS

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Filed Jan. 19, 1956, Ser. No. 560,234
8 Claims. (Cl. 22—68)

The present invention relates to die casting methods and apparatus and more particularly to the vacuum process of die casting.

It is the primary object of my invention to provide a method and apparatus for die casting in which the die cavity is evacuated while the die halves are closed.

Another object of my invention is to seal the die cavity after evacuation and prior to the introduction of the casting metal thereinto.

Another object of my invention is to utilize a metered volume of casting metal to displace the air in the passageways or metal flow channels leading to the die cavity.

Another object of my invention is to introduce the casting metal to the dies in two separate stages or steps so as to initially utilize the casting metal to seal the parting line of the die halves, and then to direct the metal into the die cavity.

Another object of my invention is to provide means for isolating the die cavity from the casting metal during the first stage of metal introduction, and provide means for exposing the die cavity to the metal during the second stage of metal introduction.

Another object of my invention is to provide selectively operable vent means for the metal flow channels, which vent means can be sealed during introduction of the metal into the die cavity.

Still another object of my invention is to provide a hydraulic and electrical control system for apparatus embodying the features of my invention.

Other objects and advantages of my invention will be apparent during the course of the following description.

In the accompanying drawings forming a part of this specification and in which like numerals are employed to designate like parts throughout the same,

FIG. 1 is a fragmentary side elevation of a form of die casting apparatus embodying the features of my invention, and showing the positions of the various parts when the dies are open.

FIG. 2 is a view of the parting face of the movable die half, taken as indicated by line 2—2 on FIG. 1.

FIG. 3 is a view similar to FIG. 1, but showing the position of the various parts when the dies are in closed position.

FIG. 3*a* is an enlarged fragmentary sectional view showing details of the gate pin arrangement, showing the position of the gate pin when it has been fully retracted, and showing in phantom outline the position of the gate pin when it is fully advanced, as in FIG. 3.

FIG. 4 is a cross-sectional view similar to FIG. 3 and showing the position of the parts during the evacuation step; the section being taken as indicated by line 4—4 on FIG. 2.

FIG. 4*a* is a fragmentary enlarged sectional view of a portion of FIG. 4, showing the vacuum port pin in retracted position in the movable die half, and showing in phantom outline the forward or closed position of the vacuum port pin.

FIG. 4*b* is a fragmentary sectional view taken as indicated on line 4*b*—4*b* of FIG. 4*a*.

FIG. 5 is a diagrammatic representation of the electrical and hydraulic circuits which may be utilized to actuate and control the described die casting apparatus.

Before proceeding with the detailed description of my

invention, I wish to outline briefly the general nature of the disclosure which is to follow.

My invention contemplates the utilization of conventional die casting apparatus which is suitably modified to adapt it to my novel process of die casting, although the lower injection pressures employed in my process make it unnecessary to design such apparatus with the massiveness and structural strength which are required for conventional die casting processes.

To evacuate the die cavity with the efficiency and speed necessary to make the vacuum die casting process commercially practicable, I have found that a relatively large evacuation port or opening in the die is considerably more desirable than the minute self-sealing die vents which have heretofore been utilized. I have also found that if the volume to be evacuated can be maintained relatively small—approaching as closely as possible the actual volume of the die cavity itself—the efficiency and speed of evacuation is greatly improved, and the complexities of sealing the evacuated space against leakage are substantially minimized.

To accomplish the foregoing I provide a sealed chamber immediately to the rear of the movable die half, which chamber is in communication with a vacuum pump or other suitable evacuating apparatus. This chamber contains an ejector plate and, in addition thereto, a control element or plate which is movable relatively to the die half and which is provided with valve rods which are adapted to open or close vacuum ports in the die. The ejector plate is provided with a pressure responsive valve element which prevents the casting metal from entering the die cavity during the evacuation thereof.

While the die cavity is under evacuation and still isolated from the casting metal, the casting metal is slowly introduced, in a predetermined volume, into the passageways and runners which lead to the die cavity. The casting metal displaces the air in these passageways, which air is vented to atmosphere, thus evacuating these metal passageways and avoiding the compression of air which conventionally occurs in these spaces.

By manipulation of the control valve rods the evacuation ports and the vent ports are then closed, and the casting metal is injected at a faster rate to cause the opening of the pressure responsive valve element and thus introduce the metal into the die cavity.

Inasmuch as the runners are free of air and the die cavity is sealed in an evacuated state, there is no significant volume of air in the path of movement of the casting metal and a homogeneous, dense, occlusion-free product is obtained at pressures which are substantially lower than conventionally employed.

The Structure

Referring more particularly to the drawings, I have shown in FIGS. 1–4 an injection die casting apparatus including a die platen **10** fixedly secured to guide rails **11** and having a die half **13** removably secured thereto by means of a die clamping plate **12**.

The other die half **14** is removably secured by means of die clamping plate **15** to a die platen **16** which is slidably mounted on the guide rails **11** for movement toward or away from the platen **10**. The clamping plate **15** includes a box-like extension provided by plates or walls **17, 18, 19** and **20** which define a closed, air tight chamber **21** between the clamping plate **15** and the die half **14**. The movable platen **16** is actuated by conventional means (not shown) which include a hydraulic cylinder **22**, shown diagrammatically in FIG. 5.

Mounted within the chamber **21** in operative association with the movable die **14** is an ejector plate **23** having fixedly secured thereto a plurality of horizontally-extending rods or pins which slidably traverse the die **14**,

and some of which serve as return pins 24 and others of which may be slightly shorter in length and serve as ejector pins 25. In addition, the ejector plate carries projecting valve rods or gate pins 26 which also traverses the die 14, but which also have limited movement relatively to the ejector plate by reason of the fact that the head 27 of the gate pin 26 is slidably retained in a cavity or bore 28 which is provided in the retaining plate 29 which serves to secure the pins 24, 25 and 26 to the ejector plate. The pins 24, 25 and 26 fit the die 14 fairly snugly so that the die bores through which they move are effectively sealed or blocked by the pins and there is some degree of frictional resistance to the relative movement between the pins and the die half 14.

Mounted rearwardly of the ejector blade 23 in the chamber 21 is a control member or control plate 30 which is slidably mounted on stop pins 31 which project rearwardly from the ejector plate and traverse the control plate, also serving as abutments for the ejector plate. The control plate 30 is fixedly secured to the ram 32 of a double-acting hydraulic ejection cylinder 33 which is secured in the die platen 16. The ram projects through a central aperture 34 in the die clamping plate 15, however, a sealing ring or gasket 35 between clamping plate 15 and platen 16 serves to maintain the chamber 21 airtight.

Fixedly secured to the control plate 30 by means of a retaining plate 36 are a plurality of valve rods or pins which project horizontally from the plate 30 and slidably traverse the ejector plate 23 and the die half 14. The valve rods include vent port pins 37 and gage port pins 38 which fit snugly in the traversing bores of the die half 14. The valve rods also include vacuum port pins 39 which fit snugly in the bore 40 of the die half 14. However, the bore 40 is provided with a series of longitudinally extending grooves 41 which terminate short of the die cavity, but which provide passageways around the pin 39 when the pin is retracted.

The chamber 21 communicates through an aperture 42 with a suction or vacuum line 43 which is connected to a vacuum producing means, such as the motor pump unit 44, shown diagrammatically in FIG. 5.

Referring more particularly to FIG. 2, it will be noted that the die half 14 is shown as a two-cavity die by way of illustration, although it is to be understood that the process and apparatus may be utilized with single or multiple cavity dies. The die half 14 has formed on the face thereof the product mold or pattern M, the complementary portion of which M', is formed in the face of the stationary die half 13. The die half 14 also has provided on the face thereof channels or troughs which are designated as runners 45 which direct the injected casting metal to gates 46 which communicate with the die cavity 47, formed when die halves 13 and 14 are in face-to-face abutment. The runners 45 extend upwardly on the die face exteriorly of the die cavities and at their upper ends 45*a* are joined to a smaller channel 48 which extends to the edge of the die 14 and serves as a vent passageway. The vent port pins 37 intersect the juncture between the runners 45 and the vent passageways 48 to block communication between them.

The die half 14 also includes an internal passageway or bore 49 which is intersected and blocked by gage port pin 38, but which communicates with the die cavity 47 when the gage pin is retracted. A vacuum gage (not shown) may be secured to the die half 14 in communication with the bore 49.

Referring once again to FIGS. 1–4, the face of die 13 is provided with a cavity or pocket 50 which is in communication with the gate passageway 46. The cavity is so located as to be slightly offset from the path of movement of gate pin 26 so that the end of the gate pin cannot enter the cavity, while at the same time the end of the gate pin is exposed to the cavity 50 when the dies are closed.

A cylindrical well or cylinder 51, having a loading aperture 52, is mounted in the stationary die platen 10 and communicates with the runners 45 and a sprue 110, when the dies are closed, by means of a well extension 53 which is provided in the stationary die 13. A hydraulic cylinder 54 serves to actuate a plunger 55 which forces the molten metal in the well 51 toward the die cavity 47.

Operation and Control

The method of operation of the apparatus will now be described, reference being had to the control diagrams of FIG. 5 to illustrate an exemplary sequence of semi-automatic operation.

In FIG. 1 the apparatus is illustrated in the die-open position with the ejector plate 23 and control plate 30 fully advanced by ejection cylinder 33, as it would appear after ejection of a casting and at the start of its operating cycle. It will be assumed that the electrical power circuit L_1—L_2 has been closed by a main switch 56 and that the hydraulic pump motor 57 and the vacuum pump unit 44 have been energized by the closing of the respective switches 58 and 59. The hydraulic system 60 is thereby operating and the chamber 21 is evacuated.

The fully retracted injection plunger 55 is in mechanical engagement with a normally-closed limit switch or cycle interrupter switch 61 which is thereby maintained in open position at the start of the cycle.

A die-closing relay 62 is connected to the power supply by a circuit 63, one side of which is interrupted by a normally-open push button switch 64, and the other side of which is completed through a normally-closed relay circuit 65 associated with a die-opening relay 66 which is not energized until the cycle of operation is almost completed.

The cycle is initiated by momentarily closing the die-close switch 64 to energize the relay 62. This immediately closes a relay holding circuit 67 which serves to maintain the relay circuit 63 after the switch 64 is released. Relay circuit 68 is also established in parallel with limit switch 61 to bypass the limit switch and close the power supply circuit L_1—L_2 to the remaining elements of the circuit. Relay circuit 69 is closed to energize one solenoid 70 of a double-solenoid-operated spring-centered normally-closed directional valve 71.

The valve 71 is an element of the hydraulic circuit 60 which includes a hydraulic pump 72 having an outlet or high pressure conduit 73 and a low pressure or return conduit 74. A pressure accumulator 75 may be provided on the high pressure side of the hydraulic system to accommodate momentarily large demands which may be made on the system. The system also includes the conventional fluid reservoir or return tank 76.

An inlet conduit 77 leads from the high pressure line 73 to the valve 71. Hydraulic fluid may selectively be directed through valve 71 to conduit 78 to cause advance of the ram of hydraulic cylinder 22, and return of the fluid through conduit 79 and through outlet conduit 80 into return line 74. This is accomplished by energization of solenoid 70. Or, upon energization of the other valve solenoid 81 the high pressure fluid is directed by valve 71 to conduit 79 to retract the cylinder 22 and return the fluid through conduits 78 and 80.

Therefore, when solenoid 70 is energized by relay circuit 69, the ram of hydraulic cylinder 22 is advanced and causes the movable die platen 16 to move toward the stationary platen 10 thus bringing the dies 13 and 14 into closed position, as seen in FIG. 3.

As the dies approach closed position, the return pins 24 abut the face of die 13 and prevent further advance of the ejector plate 23 and the control plate 30. As will more fully appear hereinafter, there is no pressure on either side of the ejection ram 32 during this step in the

cycle, so that as the platen 16 and cylinder 33 combine to advance, the ram remains stationary so that it occupies an intermediate position in the cylinder when the dies are closed.

After the forward movement of the ejector plate is arrested, the gate pin 26, which is frictionally retained by die 14, is still free to move in the cavity 28 and thus is carried forward by the die until the head 27 abuts the bottom of cavity 28.

Guide or leader pins 82 on die 14 enter bushed sockets 83 on die 13 to effect proper registry of the die faces.

The various pins and rods carried by the ejector plate and control plate are of such predetermined length that when the dies are closed and the plates are fully advanced, the vent pins 37 close off the runners 45 from the vents 48; the gage port pins 38 close off the bore 49 from communication with the die cavity 47; the vacuum port pins 39 close off the chamber 21 from communication with die cavity 47; and the gate pins 26 close off the gates 46 from communication with the runners 45, as indicated in FIG. 3.

The closing of the dies causes the closing of a normally-open limit switch 84. The switch 84 closes one side of the power supply circuit 85 to an injector relay 86, however, the other side of the circuit 85 is still maintained open by a normally-open push button switch 87 so that the relay 86 is not energized. The limit switch 84 also closes a circuit 88 to one solenoid 89 of a double-solenoid-operated spring-centered normally-open directional valve 90. The circuit 88 is completed through a normally-closed relay circuit 91 which is associated with a metering relay 92 which has not yet been energized at this stage of the cycle.

The valve 90 has an inlet conduit 93 connected to the high pressure line 73, and has an outlet conduit 94 connected to the return line 74. Hydraulic fluid may be selectively directed through a conduit 95 to cause advance of the ejection ram 32, and return of fluid through conduit 96 and outlet conduit 94. This action occurs in response to energization of the other valve solenoid 97. Or, the fluid may be directed by energization of solenoid 89, through conduit 96 with return through conduit 95 to cause retraction of the ram 32 of ejection cylinder 33. As heretofore indicated, the valve 90 has an open-center position so that when neither valve solenoid is energized, the ram 32 is not maintained under hydraulic pressure. This characteristic of the valve 90 permits the ram 32 to be displaced during the closing movement of the dies, as previously described.

Thus, when solenoid 89 is energized by the closing of limit switch 84, the ejection ram 32 is retracted and causes the control plate 30 to move rearwardly relative to the ejector plate 23 and the die 14 until projections or stops 98, provided on the rear face of the control plate 30, abut the die clamping plate 15. This retractive movement of the control plate causes retraction of the vent valve rods 37, the gage valve rods 38 and the vacuum valve rods 39 to the positions shown in FIG. 4.

The retraction of the vent port pins 37 permits the runners 45 to communicate with atmosphere through the vent passageways 48.

The retraction of the gage port pins 38 exposes the gage passage 49 to the die cavity 47.

The retraction of the vacuum port pins 39 establishes communication between the die cavity 47 and the vacuum chamber 21. It will be noted that chamber 21 is merely an extension of vacuum line 43, as chamber 21 is sealed from atmosphere during the entire operating cycle of the apparatus. Therefore, as chamber 21 is in a constant state of evacuation, it is only the relatively small volume of the die cavity 47 itself which must be evacuated during this step in the cycle. The evacuation of the die cavity 47 thus takes place very rapidly and efficiently by the action of the vacuum pump unit 44. I have found that with the exercise of reasonable care and skill in the machining of the dies 13, 14, the die surfaces at the parting line 99 will fit closely enough to prevent any significant leakage of air into the die cavity 47. As will appear hereinafter, my process even minimizes this leakage to a great extent, so that I can ordinarily attain and maintain a vacuum of about 26–28 inches of mercury in the die cavity 47 within a matter of seconds. The degree of vacuum can be observed or recorded by any suitable device connected to bore 49 in die 14. However, if desired, the dies could be provided with any conventional form of compression seal, such as soft copper or rubber, on the die faces so as to further minimize any leakage at the parting line.

At this point in the cycle, or immediately prior thereto, the molten casting metal is introduced into the well 51 in a predetermined measured volume, as by a ladle or otherwise. It will be noted that the gate pin 26 prevents communication of the runners 45 or the well 51 with the die cavity 47 so that no pressure differential exists in this area into which the molten metal is introduced.

The operator now momentarily depresses push-button switch or shot-button 87 to energize injector relay 86 through circuit 85. This immediately closes a relay holding circuit 100 which serves to maintain the relay circuit 85 after the switch 87 is released. Relay circuit 101 is established to a timer 102 which drives a rotary switch 103. Relay circuit 104 is established in series with an initially closed switch circuit 105 of the rotary switch 103 and energizes the solenoid 106 of a single-solenoid-operated spring-loaded directional valve 107. A parallel circuit 108 is established through a normally-closed relay circuit 109 of the metering relay 92 to energize a solenoid 111 of a double-solenoid-operated spring-centered normally-closed directional valve 112.

The shot-valve 107 has an inlet conduit 113 connected to the high pressure line 73 and has an outlet conduit 114 connected to the return line 74. Hydraulic fluid may be selectively directed, by energization of solenoid 106, to the inlet conduit 115 of shot-valve 112. When solenoid 106 is not energized, the fluid is directed into conduit 116 which is connected to the hydraulic cylinder 54 in a manner to cause retraction of the shot plunger 55.

Hydraulic fluid may be selectively directed, by energization of solenoid 111 of valve 112, to a metering conduit 117, which includes a manual adjustable metering valve 118, and which communicates with cylinder 54 to cause advance of shot plunger 55. The displaced hydraulic fluid is returned through conduit 116 and outlet 114 of valve 107 to return line 74. The metering valve 118 is set to restrict the flow of fluid through conduit 117 so that the shot-plunger 55 will be advanced relatively slowly. The other solenoid 119 of shot-valve 112 serves to direct fluid, when energized, into a conduit 120 which is also connected to the advance side of plunger 55, but which has no flow-restricting valve therein, such as is provided in conduit 117. A by-pass conduit 121, which includes a directional check-valve 122, is connected across conduits 115 and 120 in parallel with the valve 112 and serves to return displaced fluid through conduit 115 and outlet conduit 114 when fluid is directed to cylinder 54 through conduit 116 of valve 107, although check valve 122 prevents counter fluid flow from conduit 115 through conduit 121 to conduit 120.

With the energization of the injector relay 86, the plunger 55 is caused to advance relatively slowly and forces the molten metal ahead of it so that the metal fills the lower portion of the runners 45 and rises in the vertical runner extensions. During this movement, the air in the loading well 51 and in the runners 45 is displaced by the metal and forced out through the open vents 48.

The shot-plunger 55 continues its advancing movement until it reaches a pre-selected position at which a sufficient volume of metal has been introduced to substantially fill the runners to a point just below the upper ends 45*a*

of the runners. The metal flow passageways leading to the die cavity 47 are, at this point, substantially free of any air. It will be noted that the metal is under no back pressure and that the gate pin 26 blocks the metal from entering the die cavity 47. It will also be noted that the metal in the runners 45 acts as a form of seal to minimize any minute leakage which might tend to occur at the parting line 99 of the die faces. During this step the die cavity 47 is still in communication with the vacuum source.

The advance of the plunger 55 disengages it from the cycle interrupter limit switch 61 thereby permitting the switch to close.

When the shot-plunger 55 reaches the aforementioned preselected intermediate position (FIG. 4), it engages and closes a normally-open limit switch 123 and completes the power circuit 124 to the metering relay 92. Holding relay circuit 125 is established to maintain circuit 124 when the limit switch 123 subsequently is opened. Relay circuit 109, which was previously closed, is now open and breaks the circuit 108 to valve solenoid 111. This causes valve 112 to close and causes shot-plunger 55 to be maintained in the aforesaid intermediate position, without further movement, although high pressure fluid is still being directed into conduit 115 by energized valve 107. Another relay circuit 126 is established to the solenoid 119 of the shot-valve 112, but this circuit is maintained open by a normally-open limit switch 127. The relay circuit 91, which was intially closed, is opened by energization of metering relay 92 and breaks the circuit 88 to solenoid 89 of valve 90 which caused retraction of the ejection plunger 32. Another relay circuit 129 is established to the solenoid 97 of valve 90 through a normally-closed relay circuit 130 of the die-opening relay 66. The energization of the solenoid 97 causes ejection plunger 32 to be advanced and thereby causes the control plate 30 and its affixed valve rods 37, 38 and 39 to return to their initial position, shown in FIG. 3. The upper ends 45a of the runners are thereby sealed from communication with the vent passageways 48. The gage bore 49 is blocked from communication with the die cavity 47 and the vacuum port 40 is sealed to isolate the die cavity 47 from the vacuum chamber 21.

When the control plate 30 abuts the ejector plate 23, it engages and closes the limit switch 127 which completes the circuit 126 to solenoid 119 of the shot-valve 112. The shot-plunger 55 is thereby moved forward relatively rapidly under increased hydraulic pressure against the casting metal. The increased pressure on the molten metal, which has previously entered the pocket 50, exerts a sufficient pressure and force on the exposed end of gate pin 26 to overcome the frictional resistance of the pin and cause the pin 26 to shift rearwardly until its head 27 abuts the top of the cavity 28 in ejector plate 23. The retraction of the gate pin 26 opens the die cavity 47 to communication with the runners 45 and the casting metal is thus injected rapidly into the die cavity 47 as the shot-plunger 55 moves forward, until the evacuated die cavity is completely filled with metal under pressure. The shot-plunger 55 may now be in the advanced position shown in dotted outline in FIG. 3.

After a predetermined time interval to permit chilling of the casting, the timer-operated rotary switch 103 closes a circuit 131 which energizes the die-opening relay 66. The normally-closed relay circuit 130 is thereby opened to break the circuit 129 to solenoid 97 of valve 90 and thus relieve the pressure on the ejection ram 32. The normally-closed relay circuit 65 is also opened to break the power circuit 63 to the die-closing relay 62. However, the closed limit switch 61 now maintains the power supply L_1—L_2. The deenergization of the die-closing relay 62 opens circuit 69 to solenoid 70 of valve 71 which caused advance of the ram of hydraulic cylinder 22. A relay circuit 132 is also established to energize solenoid 81 of valve 71 and thus cause die-opening actuation of the hydraulic cylinder 22.

As the die 14 is withdrawn from the stationary die 13, the shot-plunger 55, which is still under pressure, again advances to eject the cast "biscuit" which is formed in the sprue 110 immediately ahead of the plunger. The plunger movement continues to the limit of its stroke; this position being shown in dotted outline in FIG. 1.

Upon completion of the die-opening movement, a normally-open push-button switch 133 is closed which short circuits the now-open relay circuit 130 and thereby again completes the circuit 129 to solenoid 97 of valve 90 and thus causes the ejector plate 23 and control plate 30 to be restored to their initial position, shown in FIG. 1. This movement causes ejection of the casting. The switch 133 is herein indicated as being operator-controlled, however, it could also be a limit switch responsive to the die-opening movement.

After the casting has been ejected, the operator can lubricate the head of the shot-plunger 55, a slight time interval being allowed for this purpose before the timer-operated rotary switch 103 opens the normally-closed circuit 105 to break relay circuit 104 to solenoid 106 of the shot-valve 107. Upon deenergization of solenoid 106, the spring return on valve 107 causes the hydraulic fluid to be directed to conduit 116 to cause retraction of plunger 55 to the initial position shown in FIG. 1. The shot-plunger reengages the cycle interrupter switch 61 to open it and thereby open the power circuit L_1—L_2 which results in deenergization of the entire electrical control circuit, although the motor-operated units 44 and 57 will still remain operative. The apparatus is now in condition for a repeated cycle of operation.

Applications of the Process

By evacuating the die cavity and the injection passageways leading to the die cavity, recompression of entrapped air is avoided and optimum conditions for casting the metal are attained with the resultant advantages heretofore indicated. Whereas conventional cold-chamber die casting of aluminum requires operating pressures in the range of 2,000 to 10,000 lbs. per sq. in., my process can be operated satisfactorily in the range of 500 to 2,500 lbs. per sq. in. Likewise, conventional zinc die casting processes require operating pressures in the range of 1500 to 3500 lbs. per sq. in. in contrast to comparable pressures in the range of 400 to 900 lbs. per sq. in. for my vacuum process. Thereby, not only are injection pressures substantially reduced by my process, but the size and cast of the apparatus and accessory operating equipment can also be decreased.

Although the various steps of my die casting method, as herein described, give the impression of being time-consuming, the complete operating cycle need only consume a few seconds more than the cycle time for conventional die-casting methods, and even this apparent time disadvantage is, to a large extent, offset by the time savings resulting from the decrease in the number of scrap or reject products through use of my vacuum process.

It is apparent that the principles of my process, although specifically described in relation to a cold-chamber die casting process, are equally applicable to the crucible type or goose-neck type of injection process. In fact, by isolating the die cavity from the runners during evacuation, it is possible to eliminate the conventional metal port or entry valve between the crucible and the charging cylinder, as there is no pressure differential created on the molten metal.

Other applications of the salient features of my invention will readily occur to those skilled in the art, by adapting some or all of these features to modified forms of casting apparatus, both vacuum and non-vacuum. Some illustrative examples of such adaptations follow.

By utilizing a two-stage injection process involving a preliminary introduction of a metered volume of molten metal followed by a final injection stroke, it is possible to eliminate the need for any independent seal or closure

on the entry port or aperture of the charging well or cylinder. The preliminary advance of the injection plunger serves to seal or close the loading port and thus prevents any atmospheric pressure differential when evacuation occurs in the metal flow passageways. Additionally, the preliminary introduction of a metered volume of metal permits a controlled displacement of air from the flow passageways leading to the die cavity. The two-stage injection feature can thus be utilized with distinct advantage under the following conditions.

(*a*) Merely to eliminate the need for a seal or closure for the loading or entry port in a vacuum die casting process, even if the die cavity is not isolated from the runners.

(*b*) To effect a metered displacement of air from the flow passageways leading to the die cavity in either a vacuum process or a non-vacuum vented process, so as to avoid recompression of the air in the runners when the final injection is accomplished. This can be utilized even if the die cavity is not isolated from the runners by the gate pin or like means.

Another significant feature of the process is the step of isolating the die cavity from the runners. This feature could be utilized for example under the following conditions:

(*a*) In a non-vacuum process the air in the runners could be displaced and vented before injection of the metal in the cavity.

(*b*) If the control plate herein described were eliminated, conventional self-sealing vents could be used in the die cavity as exhaust ports, although such vents would not be as effective as the large exhaust port described in my preferred embodiment. Such self-sealing vents could also be used in lieu of the vent port pins heretofore described.

Additionally, it is apparent that the vent passageway **48** need not lead to the exterior of the die **14**, but may instead be arranged to communicate with the vacuum chamber **21** so that the vacuum will supplement or aid the venting process during the initial or metering stroke of the shot plunger. Premature exhaust through the well opening **52** may be avoided by sealing the opening **52** prior to opening movement of the vent port pins **37**. Therefore, I wish it to be understood that I employ the terms "vent" and "venting" to denote the transfer or movement of the air to any area which is apart from the metal flow passages, and this area may be either the vacuum area or the area exteriorly of the die. Likewise, the term "atmosphere," as I employ it in the claims herein, is intended to encompass the reduced atmosphere which exists in the vacuum area.

It is to be understood that the form of my invention, herewith shown and described, is to be taken as a preferred example of the same, and that various changes in the shape, size, and arrangement of parts may be resorted to, without departing from the spirit of my invention, or the scope of the subjoined claims.

Having thus described my invention, I claim:

1. In a process of injection die-casting, the steps of sealing the die cavity from any communication with the metal flow passage leading to the die cavity, exhausting air from said die cavity, introducing molten metal in a predetermined volume sufficient to substantially fill said flow passage, venting the air displaced by said volume of molten metal, and then opening said die cavity to the introduction of molten metal through said passage.

2. In a process of injection die-casting, the steps of sealing the die cavity from any communication with the metal flow passage leading to the die cavity, exhausting air from said die cavity, introducing molten metal in a predetermined volume sufficient to substantially fill said flow passage, venting the air displaced by said volume of molten metal, opening said die cavity to communication with said flow passage, and displacing a volume of said molten metal sufficient to fill said die cavity.

3. In a process of injection die-casting, the steps of sealing the die cavity from any communication with the metal flow passage leading to said die cavity, evacuating said die cavity, introducing molten metal in a predetermined volume sufficient to substantially displace all of the air in said passage, venting said air from said passage, sealing said passage against further venting, sealing said die cavity in evacuated condition, opening said die cavity to communication with said flow passage, and displacing a volume of said molten metal sufficient to fill said die cavity.

4. In an injection die-casting apparatus, the combination of separable dies defining a die cavity, a charging chamber for molten metal, a flow passageway leading from said charging chamber to said die cavity, a movable injection element operatively associated with said chamber for displacing said molten metal toward said die cavity, first means for actuating said element to substantially fill said passageway with a predetermined volume of said metal, means for venting said passageway to atmosphere, sealing means responsive to the filling of said passageway for closing said vent means, and second means, responsive to closing of said vent means, for actuating said element to inject said metal into said die cavity.

5. In an injection die-casting apparatus, the combination of separable dies defining a die cavity, a charging chamber for molten metal, a flow passageway leading from said charging chamber to said die cavity, sealing means disposed in said flow passageway to completely isolate said die cavity from said charging chamber, means for evacuating said die cavity, means for sealing said die cavity in evacuated condition, means for injecting metal from said chamber into said flow passageway, and means responsive to injection of said metal for opening said first-named sealing means, whereby said die cavity communicates with said charging chamber.

6. In an injection die-casting apparatus, the combination of separable dies defining a die cavity, a charging chamber for molten metal, a flow passageway leading from said chamber to said die cavity, an injection plunger associated with said charging chamber to displace said metal toward said die cavity, first valve means responsive to abutment of said dies for exposing said die cavity to evacuation, second valve means responsive to abutment of said dies for exposing said passageway to atmosphere, third valve means responsive to abutment of said dies for sealing said die cavity from any communication with said passageway, actuating means for effecting injection of a predetermined volume of metal, means for closing said first and second valve means, and means, responsive to injection of an additional volume of said metal, for opening said third valve means, whereby said die cavity communicates with said charging chamber.

7. A combination, as defined in claim 6 wherein said last-named means is pressure responsive.

8. For use with a vacuum holding apparatus having a mold cavity for forming articles, a unitary assembly for closing off vacuum being applied to the mold cavity, applying pressure to the mass of material in the mold cavity, and ejecting an article from the mold cavity, said assembly comprising a cavity member having at least first and second bores extending therethrough, said first bore having an aperture therein for communication with a source of vacuum; a first piston extending in said first bore for closing said aperture and applying pressure to material in said cavity; first plunger means coupled to one end of said first piston for reciprocating said first piston whereby the other end thereof is moved from a position in said first bore where said other end is rearward of said aperture and said aperture communicates with the mold cavity through said first bore to a position where said other end is forward of said aperture and said aperture is closed; a second piston extending in said second bore for ejecting articles from said cavity, and second

plunger means coupled to one end of said second piston for reciprocating the other end of said second piston from a position adjacent said cavity to a position in said cavity, wherein said second plunger means is directly mechanically coupled with said first plunger means for activation thereby subsequent to movement of said first plunger means in the direction which causes said first piston to close said aperture.

References Cited in the file of this patent

UNITED STATES PATENTS

981,438	Link	Jan. 10, 1911
1,717,254	Polak	June 11, 1929
1,729,536	Brumm	Sept. 24, 1929
1,879,076	Carle	Sept. 27, 1932
1,939,831	Scheible	Dec. 19, 1933
1,954,775	During et al.	Apr. 10, 1934
1,960,992	During et al.	May 29, 1934
1,988,506	Pack	Jan. 22, 1935
2,112,343	Lester	Mar. 29, 1938
2,137,764	Wagner	Nov. 22, 1938
2,206,211	Wagner	July 2, 1940
2,243,835	Brunner et al.	June 3, 1941
2,494,071	Veale	Jan. 10, 1950
2,532,256	Holmes et al.	Nov. 28, 1950
2,582,029	Halward	Jan. 8, 1952
2,637,882	Plott	May 12, 1953
2,717,433	McGervey	Sept. 13, 1955
2,774,122	Hodler	Dec. 18, 1956
2,785,448	Hodler	Mar. 19, 1957

FOREIGN PATENTS

1,076,174	France	Apr. 21, 1954
726,551	Great Britain	Mar. 23, 1955
370,613	Germany	Mar. 5, 1923