Nov. 1, 1960 C. W. OHSE 2,958,104

VACUUM DIE CASTING PROCESS AND APPARATUS

Filed April 21, 1958 6 Sheets-Sheet 1

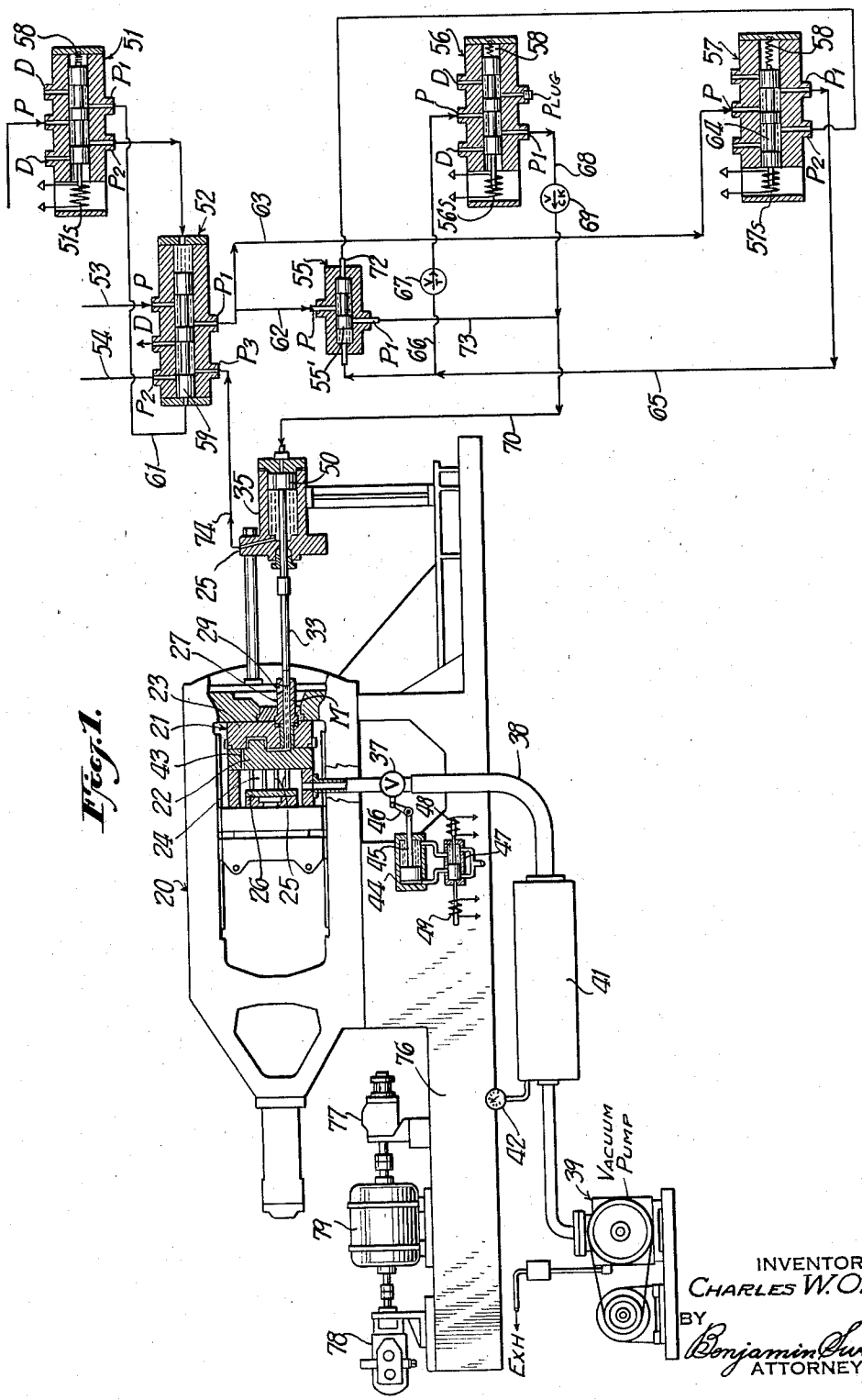

Fig. 1.

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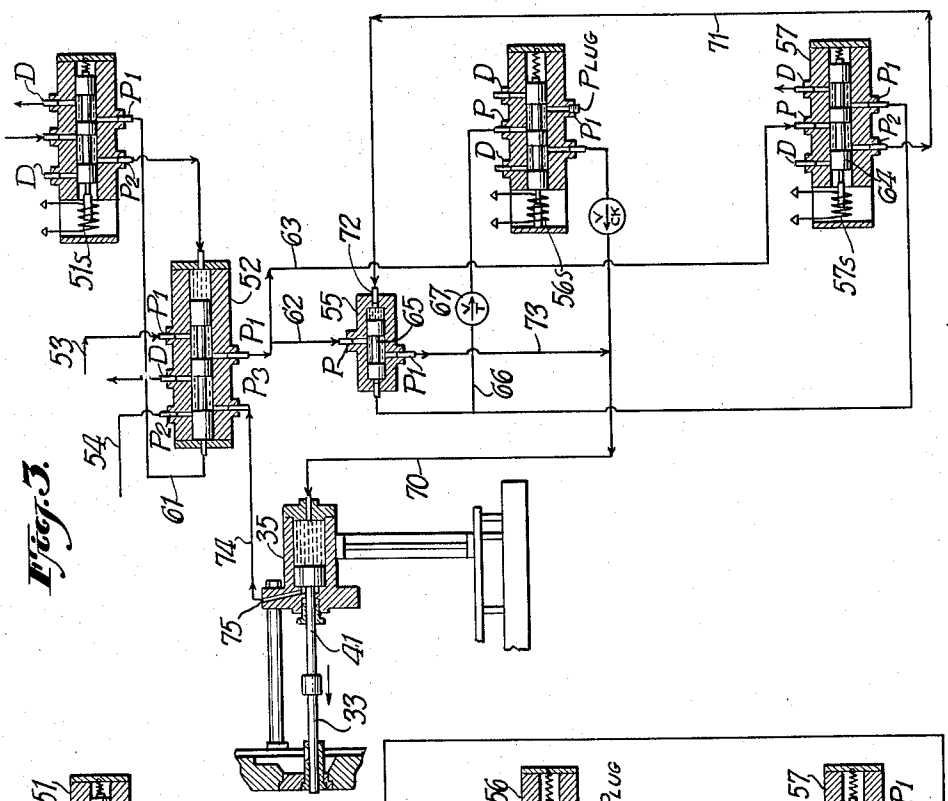

Fig. 3.

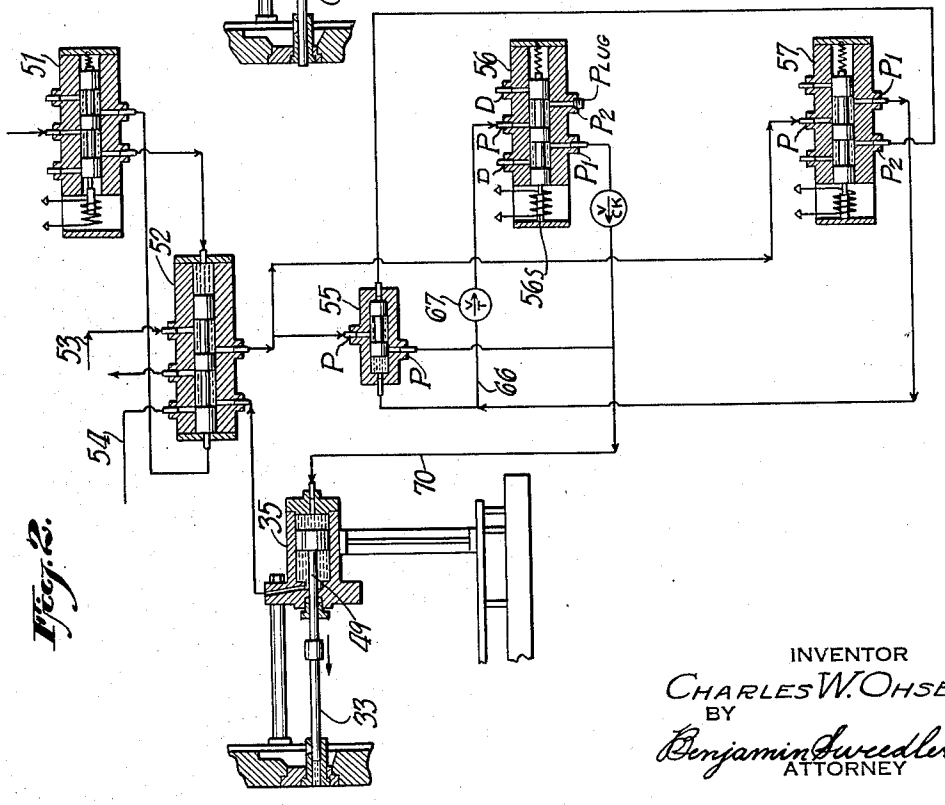

Fig. 2.

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Fig. 6.

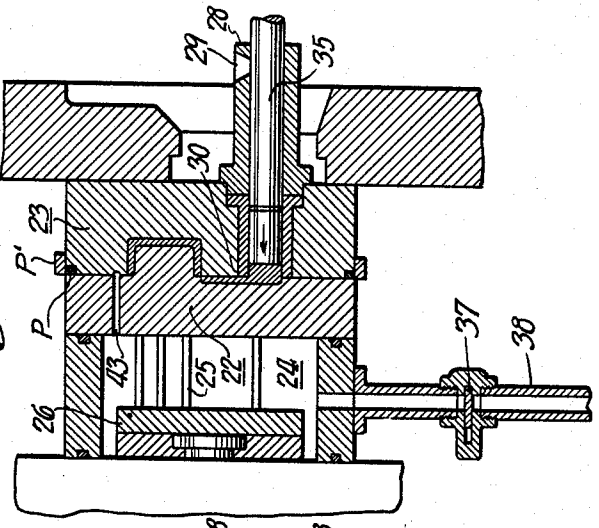

Fig. 5.

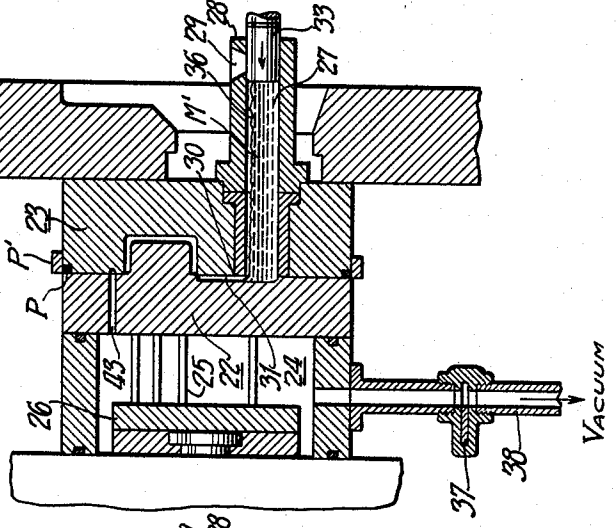

Fig. 4.

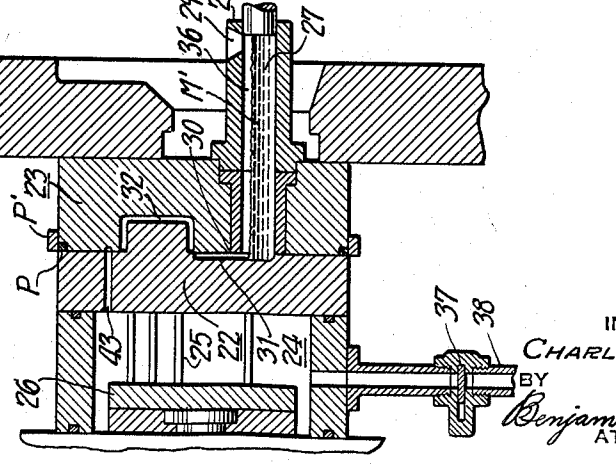

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Fig. 8.

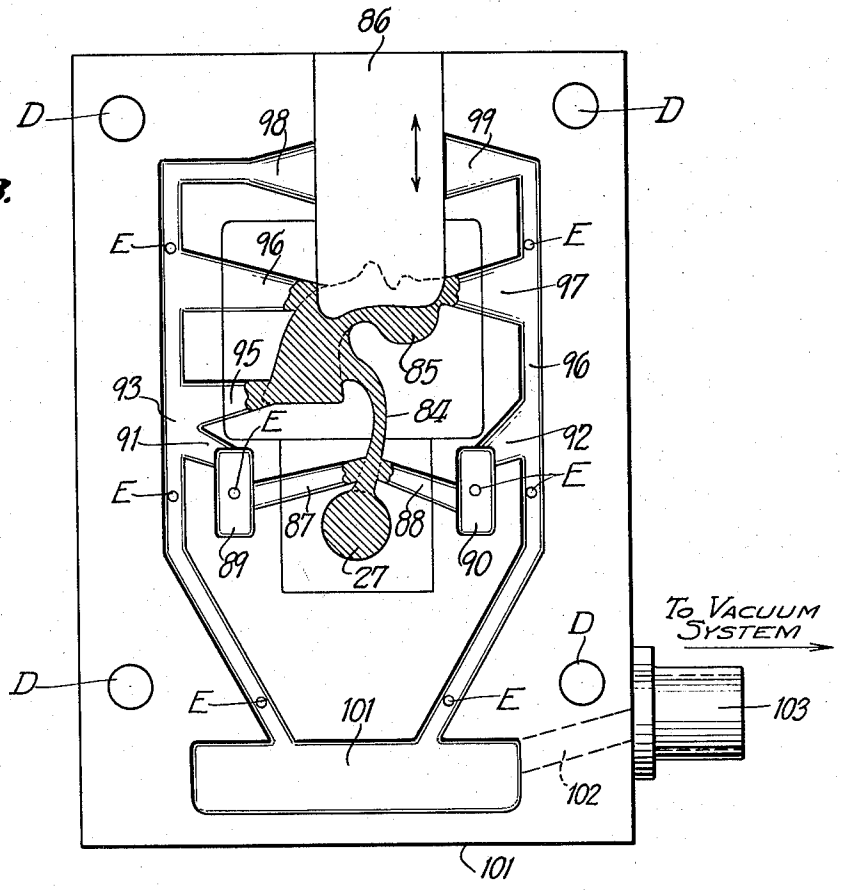

Fig. 7.

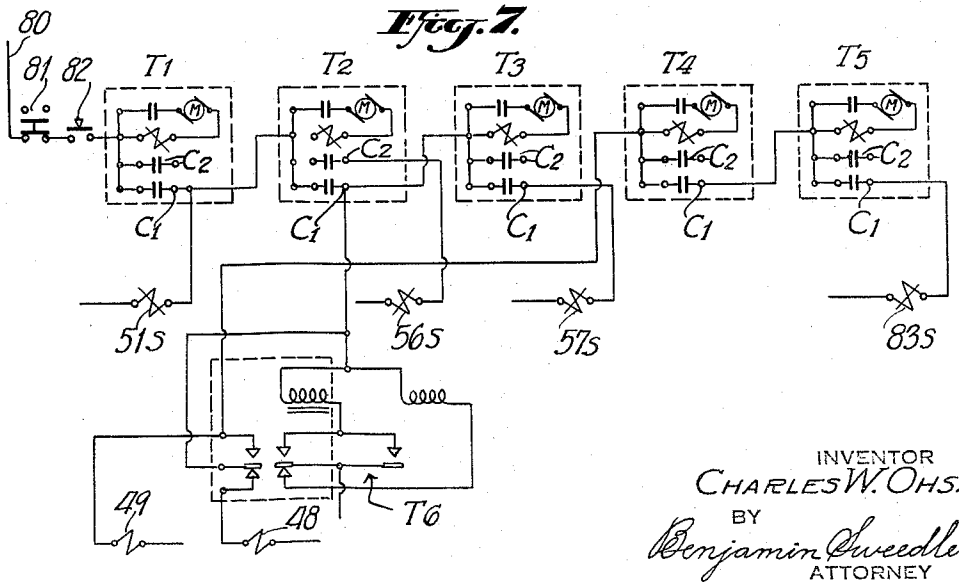

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Fig. 10.

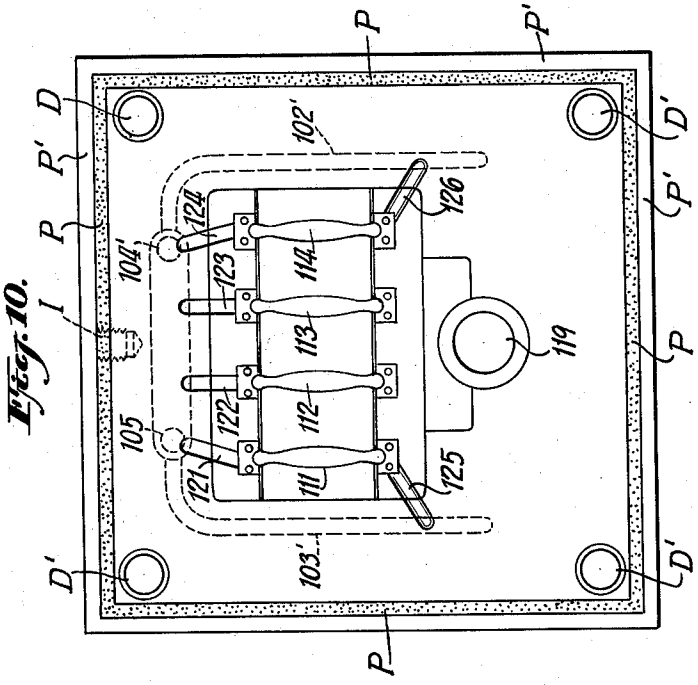
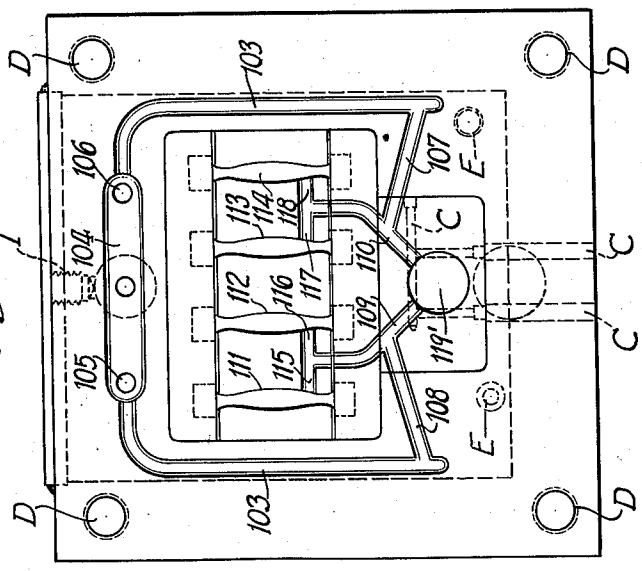


Fig. 9.



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VACUUM DIE CASTING PROCESS AND APPARATUS

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Fig. 12.

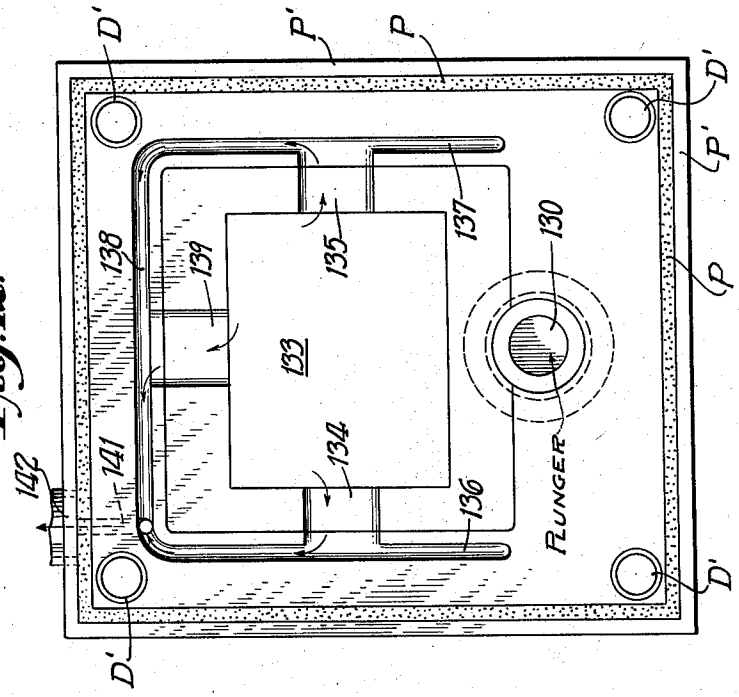
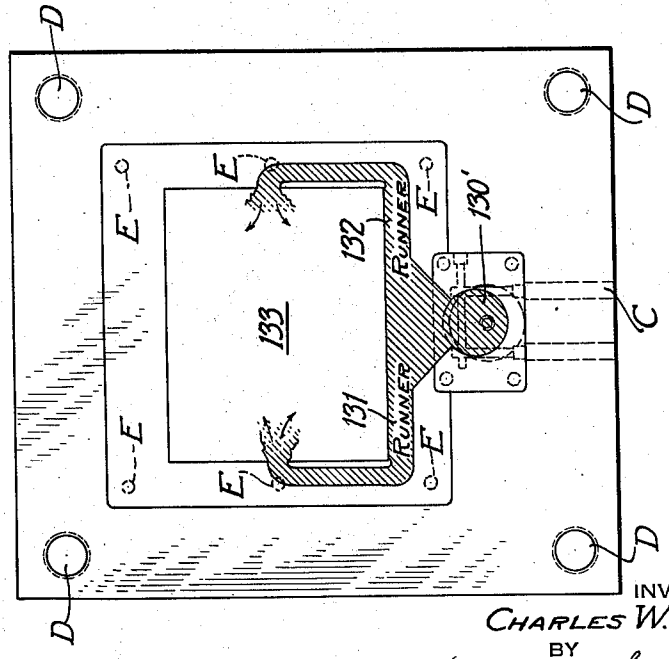


Fig. 11.



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United States Patent Office

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VACUUM DIE CASTING PROCESS AND APPARATUS

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Filed Apr. 21, 1958, Ser. No. 729,920

7 Claims. (Cl. 22—68)

This invention relates to vacuum die casting and more particularly to process and apparatus for die casting metals under vacuum.

Vacuum die casting techniques have been described in the literature at least as early as 1905. Attempts made to apply such vacuum techniques to existing relatively high speed die casting equipment have encountered numerous difficulties and objections, among the more important of which may be mentioned:

(1) The equipment is unnecessarily complicated with consequent high first cost and relatively high maintenance expenses;

(2) In operation, it is not unusual for freezing of the molten metal to take place in the runners leading to the die cavity, and premature freezing of molten metal to occur in the die cavity with consequent production of poor quality castings and excessive quantities of rejects. Freezing in the runners seriously interferes with operation of the equipment in that it requires stoppage of the equipment to clean out the plugged runners caused by such freezing;

(3) Vacuum techniques heretofore known do not result in the substantially complete removal of air and other gases, particularly in the metal chamber and runners connecting the metal chamber with the die cavity. Air and gases entrapped in the metal chamber and runners are at times entrapped in the metal when the latter is introduced into the die cavity and deleteriously affect the quality of the castings. Thus, for example, when the molten metal is forced through the metal chamber into the die cavity, the metal is agitated, entrapping air and gases present in the metal chamber within the interior of the body of molten metal, which air and gases cannot escape when the body of molten metal is subjected to vacuum in the die cavity;

(4) Some vacuum techniques are not readily adapted to existing die casting machines without very extensive reorganization of the machine so much so as to require costly changes in existing equipment to adapt them for vacuum operation.

It is among the objects of the present invention to provide a vacuum die casting technique which is efficient, which results in good quality castings, which results in a marked reduction in the number of rejects or inferior quality castings, and which can be carried out in equipment simple in design and hence economic in first cost and to maintain and operate.

It is another object of this invention to provide vacuum die casting process and apparatus substantially free of the above noted objections to prior known vacuum die casting procedures and equipment.

Still another object of this invention is to provide a vacuum die casting process, which process with little modification of existing relatively high speed equipment can be carried out efficiently in such modified equipment.

Still another object of the present invention is to provide a vacuum die casting procedure in which entrapment of air and gases in the molten metal during the casting operation is minimized, if not completely avoided.

Other objects and advantages of the present invention will be apparent from the following detailed description thereof in which the description for the most part will be in terms of the application of the invention to die casting metals. It will be understood, however, the invention is not limited to the casting of metals.

The present invention is particularly applicable to existing relatively high speed die casting machines involving relatively movable die members which communicate with a metal chamber generally extending longitudinally relative to the die cavity and communicating at one end therewith through a runner or runners and having a feed port at the other end. In carrying out the process of this invention in such equipment, the die members are first closed to form the die cavity. Thereafter, the charge of molten material is introduced through the feed port into the metal chamber. A plunger slowly moves this charge toward the die cavity and away from the port leaving at all times a space free of molten material above the charge in the metal chamber communicating with the die cavity. This movement of the feed plunger also effects sealing of the feed port. After the feed port is sealed, the die cavity and the communicating space in the metal chamber is subjected to a relatively high vacuum to remove air and gases from the die cavity and the communicating spaces.

During the initial stages of vacuum application the charge of molten metal is momentarily held stationary in the feed chamber. This is accomplished by causing the plunger to dwell or stop in its movement after the feed port is sealed. During this momentary dwell, air and gases in the space above the metal charge and in the runner and die cavity are evacuated. The charge of metal is then moved rapidly into the evacuated die cavity while the vacuum is maintained thereon. Thus the molten metal moves through the evacuated runner or runners and die cavity, into the latter preventing entrapment of air and gases by the molten metal as it is fed into the die cavity. Thereafter, the vacuum is interrupted, the dies moved apart and the casting removed from the open die by the usual ejector pins or fingers.

It was not unusual, in prior known vacuum die casting procedures, for the molten metal charge in its movement into the die cavity to entrap air present in the metal chamber and/or the runner. Such entrapment is aggravated by the agitation of the molten metal which takes place as it is forced into the die cavity.

As contrasted with these prior known procedures, in the present invention each charge is slowly fed within the metal chamber toward the die cavity to maintain at all times during this slow feed a space above the metal charge which, through the runner, is in communication with the die cavity. After the feed port has been sealed, a relatively high vacuum, preferably within the range of 24 to 30 inches of mercury at the source, is pulled on the die cavity. This substantially completely evaculates the die cavity, the runner or runners communicating therewith, and the free space above the metal charge in the metal chamber, as well as affording entrapped gases in the metal an opportunity to escape. During this period, which generally is not more than one second in duration and may last from about one-eighth to one second, the molten metal charge in the metal chamber remains stationary. In other words, movement of the feed plunger is interrupted and it is maintained stationary, so as not to feed the molten metal, momentarily after the feed port has been sealed and while the die cavity and communicating runners and the communicating free space above the metal charge is subjected to vacuum. Thereafter, the metal charge is introduced rapidly into the die cavity, the time required for the plunger to effect such rapid introduction of the molten metal into the die cavity may be

of the order of about one-twentieth of a second. By having the period during which the feed plunger is maintained stationary short, not exceeding about a second, but long enough to effect complete evacuation of the die cavity and runner and the aforesaid free space and thereafter rapidly introducing the molten metal charge, freezing of metal within the runner and communicating metal chamber is avoided.

The apparatus of this invention, preferably, involves a die block consisting of a cover half and an ejector half provided with suitable packing along the parting line to insure a gas-tight seal when the halves are brought in abutment, i.e., when the die cavity is closed, except for the vents which lead from the die cavity to the vacuum system. The vacuum system, for example, may communicate with the ejector box or with suitable exhaust channels into which lead the vents from the die cavity. The communication between the vacuum system and the die cavity is controlled by a valve which, when open, places the die cavity in communication with the vacuum system, and, when closed, interrupts the vacuum in the die cavity. Suitable timing mechanism is provided for actuating the parts in the desired timed sequence, to close the feed port after a charge of molten metal has been introduced into the metal chamber, first slowly move the metal feed plunger until the feed port is sealed by the plunger, then open the valve controlling the vacuum so that the die cavity is subjected to vacuum, then maintain the feed plunger stationary, thereafter move the feed plunger relatively rapidly to introduce the charge into the die cavity while the vacuum is still pulled thereon, then close the aforesaid valve controlling the vacuum, and thereafter move the die halves relative to each other to open the die and eject the casting from the open die.

In the accompanying drawings, forming a part of this specification and showing, for purposes of exemplification, preferred forms of this invention, without limiting the claimed invention to such illustrative instances:

Figure 1 is an elevational view, partly in section, through a vacuum die casting machine embodying the present invention and showing the valve mechanism for controlling the operation of the feed plunger; in this figure, the feed plunger is shown in the position it occupies just after the charge of molten metal has been introduced into the metal chamber;

Figure 2 is a fragmentary diagrammatic view showing the valve mechanism for operating the feed plunger in the next stage of operation, namely, with the feed port closed and with the metal charge as well as the plunger in the dwell or stationary stage;

Figure 3 is another fragmentary diagrammatic view showing the valve mechanism for operating the feed plunger to effect movement of the metal charge into the die cavity, and showing the next stage after the dwell stage shown in Figure 2;

Figure 4 is an enlarged fragmentary horizontal section showing the die halves, communicating metal chamber and the charge therein just after it has been introduced into the metal chamber, and also showing the valve controlling the application of vacuum;

Figure 5 is a similar view showing the succeeding stage of operation, namely, the dwell stage, in which the metal feed port is sealed and the valve controlling the application of vacuum is open, so that the die cavity, communicating runner and space in the metal chamber above the metal charge as well as the metal charge while stationary and thus in a static and non-agitated state, is subjected to vacuum;

Figure 6 is a similar view showing the next stage of operation, namely, with the metal charge introduced into the die cavity and the vacuumi nterrupted;

Figure 7 is a diagrammatic view of one form of timing mechanism which can be used to effect the operation of the parts of the vacuum die casting equipment in desired timed sequence;

Figure 8 is an enlarged front elevational view of the ejector half of a die and shows a form of die in which the die cavity communicates with the vacuum system at the parting line between the cover half and ejector half of the die and in an area on the parting line below the die cavity;

Figures 9 and 10 show, respectively, elevational views of the ejector half and cover half of another form of die which is designed to simultaneously produce a number of castings and in which the connection to the vacuum system takes place through the ejector box with which the back portion of the ejector half communicates; and

Figures 11 and 12 are, respectively, elevational views on an enlarged scale of the ejector half and cover half, respectively, of a die in which the die cavity communicates with the vacuum system through a vacuum line leading from the parting line of the die in the area thereof above the die cavity.

Referring to Figure 1, **20** is the frame of a die casting machine of the high speed type which, as customary, comprises a die block **21** consisting of an ejector half **22** and a cover half **23**. The cover half **23** is fixed in the frame **20**. The ejector half **22** is movable relative to the cover half **23**, being slidably mounted for this purpose so that it can move towards and away from the cover half **23**. In the position shown in Figure 1, the ejector half **22** is in the abutting or die closed position.

As conventional, the ejector half **22** is provided with passageways extending therethrough into the ejector box **24** at the back of the ejector half **22**. Casting ejector pins or fingers **25** are carried by the movable ejector head **26**, which fingers when the die is open pass through the passageways in the ejector half **22** to effect the discharge of the casting.

Communicating with the cover half **23** is a metal chamber **27**. This chamber extends in a generally longitudinal direction and at end **28** is provided with a feed port **29** and at the other end **30** communicates with a runner **31** leading to the die cavity **32** produced by the cover half **23** and ejector half **22** when in the closed position of the dies, as shown in Figures 1, 4, 5 and 6. A feed plunger **33** is suitably mounted for reciprocatory motion on the frame of the machine. This plunger is shaped as shown in Figure 6 so that it snugly fits within the metal chamber **28**. In the plunger position shown in Figure 4, feed port **29** is open. In the plunger position shown in Figure 5, the plunger **33** seals the feed port **29**.

As hereinafter described more fully, plunger **33** is actuated by a pressure fluid cylinder **35**, suitably mounted on the frame of the machine. Pressure fluid is supplied to and exhausted from the pressure cylinder **35** by a system of valves hereinafter described, operated in predetermined timed sequence so that after a charge M′ is introduced into the metal chamber **28**, which charge is controlled in volume so that it leaves a substantial free space **36** in the metal chamber above the charge M′, plunger **33** is first moved slowly to seal the port **29**. During this slow movement the molten metal M′ is moved towards the rear of the metal chamber without, however, completely filling the metal chamber or the inlet portion of the runner **31** communicating with the metal chamber. In other words, free space **36**, while of somewhat less depth than shown in Figure 4, still remains as shown in Figure 5 in the metal chamber **27** when feed port **29** is sealed and this free space **36** through the inlet portion of runner **31** is in communication with the die cavity **32**.

Thereafter, movement of plunger **33** stops momentarily; the molten metal M′ is thus brought to a stationary and non-agitated state in the metal chamber as shown in Figure 5. Valve **37** in the line **38** connecting the die cavity **32** through the exhaust channels hereinafter described with the vacuum system, is opened and the die cavity **32**, runner **31** and communicating space **36** above the metal charge M′ subjected to vacuum. Momentary stoppage of plunger **33** may last from about one-eighth

to one second to permit substantially complete evacuation of the die cavity, runner or runners and space 36. The exact time will depend on the volume of the charge M' and the equipment, e.g., the size of the metal chamber. The smaller the volume of the charge the shorter the dwell and generally the faster the rate of introduction into the die cavity. After this momentary stoppage or dwell of plunger 33, it is actuated to move rapidly to introduce the metal charge into the die cavity. During this rapid movement of the plunger the valve 37 controlling the vacuum remains open. When the plunger has completed its forward movement and the charge has been introduced into the die cavity valve 37 is then closed as shown in Figure 6.

The vacuum system comprises a vacuum pump 39 which communicates with a vacuum tank 41 provided with a gauge 42 and connected by line 38 having valve 37 therein with the die cavity as hereinafter described more fully. In the modification of Figure 1 the vacuum line 38 leads into the ejector box 24 connected through vents 43 (Figures 4, 5 and 6) with the die cavity 32, thus providing for direct communication through these vents 43 between the die cavity and vacuum system when valve 37 is open. Pump 39 provides a high vacuum in tank 41, within the range of 24 to 30 inches of mercury; the higher the vacuum the better.

It will be understood the showing in the drawings of the vacuum system is exemplary only; a vacuum tank communicating within a vacuum pump may be used which is connected to the die cavities of a number of die casting machines instead of the single machine shown in Figure 1. Also, as explained more fully hereinafter, the connection between the die cavity and the vacuum system need not necessarily be through the ejector box as in the modification of Figure 1.

Valve 37 in the vacuum line 38 is actuated by a pressure cylinder 44 having a piston stem 45 communicably connected with the lever 46 which effects opening and closing of the valve 37. The flow of pressure fluid to and from cylinder 44 to effect movement of lever 46 to open and close valve 37 is effected by a controlling valve 47 provided with solenoids 48 and 49. Solenoid 48 when energized effects operation of the pressure cylinder 44 to open the valve 37 and the other solenoid 49 when energized actuates the valve 37 in the opposite direction to close it.

The valve mechanism for controlling the operation of pressure cylinder 35, which through its piston stem 50 integral with or connected to feed plunger 33 effects the movement of this feed plunger, as hereinabove described, consists of five interconnected valves 51, 52, 55, 56 and 57. Valve 51 controls the flow of pressure fluid to and through valve 52, the main valve for controlling the operation of the feed plunger 33 and which main valve communicates through lines 53 and 54 with the source of fluid pressure. Valve 55 is a pilot valve which controls the flow of pressure fluid to cylinder 35 so as to effect initial slow movement of the feed plunger 33, its dwell and later rapid movement to introduce the metal charge M' into the die cavity 32. Valve 56 cooperates with valve 55 to control the flow of pressure fluid to cylinder 35 so as to effect initial slow movement of the feed plunger 33, and thereafter the dwell of the plunger to maintain the metal charge M' stationary during the initial vacuum stages. Valve 57 cooperates with the pilot valve 55, as hereinafter more fully explained, to give the initial slow movement and in the desired timed sequence the later rapid movement of the plunger 33 to effect the introduction of the metal charge M' into the die cavity 32.

In the case of the valves 51, 52, 56 and 57, the drain ports are indicated by D, the other ports by P, P_1, P_2, P_3, depending on the number of ports in the valve. The solenoids for actuating each valve are indicated by the same reference character as identifies the valve followed by the letter S. Thus, the solenoid for the valve 51 is 51S, that for valve 56 is 56S and that for valve 57 is 57S. The spring of each of the valves 51, 56 and 57 which effects return of the valve stem or spool when the solenoid of that valve is de-energized, is shown at 58.

The solid lines in each of Figures 1, 2 and 3 show the conduit connections between the various valves hereinabove described and with the pressure cylinder 35 which effects actuation of the feed plunger 33. Those lines in each of Figures 1, 2 and 3 bearing arrows show the flow through the valves and communicating conduits with the valve stems or spools positioned as shown in Figures 1, 2 and 3, respectively.

In the case of Figure 1, the valves are shown in the position they occupy just after a charge of molten metal has been introduced into the metal chamber 27 with the feed plunger 33 at the beginning of its feed stroke. As shown in Figure 1, the solenoid 51S of valve 51 has just been energized to position the valve spool of valve 51 so that pressure fluid flows through port P, exits through port P_2, and actuates the valve spool 59 in valve 52 to move it to the extreme left, viewing Figure 1. Pressure fluid exits through line 61 flowing through port P_1 of valve 51 to one of the drain ports D in the return portion of the pressure fluid system with which valve 51 communicates.

With the valve spool 59 of valve 52 in this position, pressure fluid enters through line 53, flows through ports P and P_1 through the line 62 into the pilot valve 55, which, in the position shown in Figure 1, closes the line 62. Hence, flow takes place through the branch line 63 into the port P of valve 57, which has its valve spool 64 positioned as shown in Figure 1 when solenoid 57S is de-energized. The pressure fluid exits through port P_1, flows through line 65 into the pilot valve 55 maintaining the valve spool 55' therein in the closed position shown in Figure 1. A branch line 66 leads from line 65 and has therein a needle valve 67. This branch line communicates with port P of valve 56. In the position shown in Figure 1, pressure fluid flows through needle valve 67 into port P of valve 56 through port P_1, line 68 having check valve 69 therein, which check valve permits flow through the line 68 towards the pressure cylinder 35 but prevents flow in the opposite direction. Accordingly, the pressure fluid which has been throttled in its flow through the needle valve 67 actuates the piston 50 in pressure cylinder 35 to effect a slow movement of the feed plunger 33 from the position shown in Figures 1 and 4 to the position shown in Figure 5. While pressure fluid is supplied to cylinder 35 to move the piston from right to left (Figure 1) exhaust of pressure fluid takes place through line 74, port P_3 and drain port D of valve 52.

When the feed plunger reaches the position shown in Figure 5, its motion is stopped. This is effected by the timing mechanism hereinafter described, energizing solenoid 56S of valve 56 to move the valve spool therein to the position shown in Figure 2. In this position, flow cannot take place through the valve 56 because port P_2, which then communicates with port P is plugged. Hence, the pressure fluid flowing through the branch line 66, needle valve 67, into port P of valve 56 does not flow onto the hydraulic cylinder 35. Accordingly, the piston 50 is then stationary and the associated feed plunger and the charge of molten metal M' in metal chamber 27 is maintained stationary or static. It will be noted from Figure 2 that no flow takes place through line 70 (shown by the lack of arrows on this line in Figure 2) connecting line 68 with the hydraulic cylinder 35.

At the termination of the dwell stake shown in Figure 2, which may be from about one-eighth to a second in duration, the timing mechanism actuates the solenoid 57S of valve 57 to move the valve spool 64 to the position shown in Figure 3. In this position of the valve spool 64, pressure fluid flows through line 63, enters the port P and leaves through P_2, flowing through line 71 into the port 72 of pilot valve 55. This pressure fluid

moves the piston head 65 to the position shown in Figure 3, thus placing the ports P and P_1 of the pilot valve 55 in communication so that flow of pressure fluid now takes place from line 62 through line 73 communicating with the line 70. Thus, pressure fluid will bypass the needle valve 67 and flow directly through lines 73, 70 into the hydraulic cylinder 35 effecting rapid actuation of the feed plunger 33 to introduce the charge of molten metal M' into the die cavity 32.

After formation of the casting as customary the dies are opened. The moving die member through suitable cam mechanism (not shown) trips the main switch when it reaches the open position breaking the contacts in the timers as hereinafter more fully described. This de-energizes the timers and the solenoids in valves 51, 56 and 57. When solenoid 51S is thus de-energized, spring 58 moves the valve spool therein so that pressure fluid is supplied through line 61 to the valve spool 59 actuating it to place ports P_2 and P_3 of valve 52 in communication. Pressure fluid flows from line 54, through these ports, line 74 into end 75 of the pressure cylinder 35 to actuate the piston therein in the opposite direction. The pressure fluid exhausts from pressure cylinder 35 through line 70, branch line 73, pilot valve 55, port P_1 and drain port D of valve 52 communicating with the fluid pressure system.

In the modification of Figure 1, the frame 76 of the machine has mounted thereon pumps 77 and 78 actuated by a motor 79 to supply pressure fluid to the valve system hereinabove described as well as to other pressure cylinders through suitable connections (not shown). It will be understood that the pressure fluid system, as conventional, may involve one or more accumulators for supplying pressure fluid such as oil, to each operative part actuated thereby.

The timing mechanism for effecting operation of the hereinabove described valves and the valve 37 controlling the vacuum pulled on the die cavity and the charge of molten metal fed thereto is shown diagrammatically in Figure 7. Any desired timing mechanism may of course be used. The showing of Figure 7 is exemplary only, and the invention is not limited to the type of timing mechanism diagrammatically shown in this figure. Since the timers individually are of a conventional type and are well known, they are described briefly and shown in a manner commonly employed by engineers familiar with electrically operated timers.

In Figure 7, five timers are shown indicated by the reference characters T_1, T_2, T_3, T_4 and T_5. Each timer, as customary, has therein a small electric motor M which effects opening and closing of switch contacts involving a stationary contact member and a movable contact member arranged to be actuated by the motor, the switches in each timer being identified by the reference characters C_1, C_2, etc. It will be understood that each timer also contains conventional relays for effecting desired timed delay whenever desired. Timer T_2 communicates with the time delay mechanism T_6 which is in circuit with the solenoids 48 and 49, effecting opening and closing of valve 37 in the vacuum line. All of the timers T_1 to T_5, inclusive, and the time delay mechanism T_6 are supplied by current from the main power line 80. In this line is disposed the machine switch 81 which is arranged to be closed by the movable die half engaging an arm of the switch to effect its closing when the hydraulic mechanism actuates this movable die half to close the die. Switch 81, as noted above, is opened when the movable die half returns to its fully open position, thus de-energizing the timers and setting them for a repeat of the cycle of operation hereinafter described.

Disposed in the power line 80 is a foot switch 82. Each time this switch is closed (provided switch 81 is also closed) timer T_1 is energized and the timers go through a complete cycle of operation.

In operation, with switch 81 closed, when the movable die half is actuated to close the die, the operator depresses the foot switch 82 after the desired charge has been fed manually or automatically into the metal chamber through the feed port 29. Upon closing the foot switch 82 timer T_1 is energized. This timer involves a small time delay before closing the switch C_1 therein as a safety measure to give the operator ample time for the introduction of the charge. When switch C_1 of timer T_1 closes, solenoid 51S of valve 51 is energized to actuate valve 52 to the position shown in Figure 1. Switch C_2 of timer T_1 is not used; a timer having only one switch could, of course, be employed. At the same time, timer T_2 is energized. This timer is set for the length of time required for feed plunger 33 to move from the position shown in Figure 1 and Figure 4 to that shown in Figure 5. Switch C_2 of timer T_2 closes, energizing solenoid 56S, thus causing the pressure fluid to be supplied to the pressure cylinder 35 through the needle valve 67 as hereinabove described, causing slow travel of the feed plunger for the time interval at which timer T_2 is set, which time interval, as noted, is sufficient to cause the plunger 33 to move past the port 29 to seal this port. At this point, switch C_2 in timer T_2 opens, de-energizing the solenoid 56S and causing the spring 58 in valve 56 to move the valve stem therein to the position shown in Figure 2. At this point, flow cannot take place through valve 56 and, hence, the plunger and the metal charge in the metal chamber are maintained stationary. At the same time switch C_1 in timer T_2 closes energizing the time delay mechanism T_6 which energizes solenoid 48 to open the valve 37, placing the system under vacuum. Timer T_3 is also energized at the same time as T_6.

Timer T_3 is set for the required time delay for evacuating the die cavity, the runners communicating therewith and the free space above the metal charge in the metal chamber 27, i.e., the time during which plunger 33 remains stationary. When this time has elapsed, switch C_1 in timer T_3 closes, energizing the solenoid 57S of valve 57. This causes pressure fluid to flow directly through the pilot valve 55 to the pressure cylinder 35 as hereinabove described, moving the plunger forward relatively rapidly to introduce the metal charge into the die cavity. During this period, time delay relay T_6 controls the length of time the evacuation remains in effect which is until the complete charge has been introduced into the die cavity. When this has been effected, the time delay relay T_6 energizes solenoid 49 to close the valve 37. At the same time, timer T_4 is energized.

Timers T_4 and T_5 are set for the required dwell to enable the casting to harden, usually aided by the circulation of a cooling medium through the dies, before the die opens. When switch C_1 of timer T_4 is closed, timer T_5 is energized with consequent closing of switch C_1 of timer T_5 effecting energization of the solenoid 83S (Figure 7) which controls the opening movement of the die halves to open the die and to effect the discharge of the casting.

When the die reaches its fully open position, as noted above, the main switch 81 is opened automatically by the moving ejector half of the die block. De-energization of the timers, accordingly, takes place; also, solenoid 51S of valve 51 is de-energized, causing the spring 58 of this valve to move the valve spool therein to the position where port P communicates with port P_1 of valve 51. Pressure fluid flows through valve 51 into and through line 61 moving the valve spool 59 of valve 52 to cause pressure fluid to flow from line 54 through valve 52 into the pressure cylinder 35 to move the piston therein from left to right, viewing Figure 1, i.e., return the piston 50 to the position shown in Figure 1. Pressure fluid exhausted from cylinder 35 during this motion of the piston flows through the pilot valve 55, valve 52, to the drain port D of valve 52 which drain port communicates with the pressure fluid system.

When the die halves are again closed, and the operator

closes the foot switch 82, the sequence hereinabove described is repeated.

One of the die halves has suitable packing P, such as synthetic rubber resistant to high temperature or other plastic or packing material, completely surrounding the die cavity to form a gas tight seal when the die is closed. It will be appreciated that different dies are used depending on the objects to be cast. All dies employed in the apparatus embodying this invention are designed so that the vents are small in cross section, generally not greater than .006 inch, to prevent flow of molten metal thereinto from the die cavity. The cross sectional area of the vents at the point they communicate with the die cavity is important. If too large, metal will enter the vents and interfere with satisfactory operation. By having the vents at the point they communicate with the die cavity of a cross sectional area not exceeding 0.006 inch, I have obtained satisfactory operation.

In the apparatus of this invention, all portions of the die cavity, the runners, channels and passageways communicating therewith are vented and in communication with the vacuum system to minimize the entry of air or other gases into contact with the molten metal during the casting operation.

Several different types of dies are shown, for purposes of exemplification, in Figures 8 to 12, inclusive. These drawings are not to scale and show the vents on an enlarged scale for clarity of illustration.

In Figures 8 to 12, inclusive, the ejector openings in the ejector half of the die through which the ejector pins or fingers move to effect removal of the casting are indicated by the reference character E, the locating dowels on the ejector half by the reference character D, the cooperating dowel openings on the cover half of the die by D', and the packing disposed at the marginal edges of a die half by the reference character P.

In Figure 8 the metal chamber 27 communicates through a runner 84 with a die cavity 85 shaped as shown in this Figure. Communicating with the upper portion of the die cavity is a slide housing 86 which is employed in the case of dies designed to produce an opening or depression in the casting, which opening or depression is formed by a slidable member movable into the die cavity to occupy a portion thereof, thus forming a depression in the casting. Such movable member is commonly known in the art as a slide.

In accordance with the present invention, the die cavity 85, as well as the runner 84 and slide housing 86, are adequately vented to insure complete evacuation thereof as well as of the free space above the metal charge in chamber 27. For this purpose, vents 87 and 88 extend from the opposite side of the runner 84 into ducts 89, 90, in turn vented through the vents 91 and 92, respectively. The latter vents 91 and 92 communicate with the exhaust channels 93 and 94, respectively. The die cavity 85 is provided with three vents 95, 96 and 97; vents 95 and 96 communicate with exhaust channel 93 and vent 97 with the exhaust channel 94. The slide housing 86 is connected through vents 98 and 99 with the exhaust channels 93 and 94, respectively. Each of the vents 87, 88, 95, 96 and 97 are small enough to prevent entry of molten metal thereinto but still large enough to permit evacuation of the runner and die cavity with which they communicate. These vents where they join the die cavity have a cross sectional area not exceeding about 0.006 inch and desirably flare outwardly toward the exhaust channels.

The exhaust channels 93 and 94 communicate with a manifold 101 connected by a passageway 102 with the port 103 to which the vacuum line 38 is connected. Port 103, it will be noted, is disposed on the side of the die block beneath the die cavity at the parting line of the die halves. The cover half of the die (not shown) is provided with packing so that when the die is closed the die cavity is sealed except for the vents 95, 96 and 97 communicating with the exhaust channel, and the runner 84 communicating with the metal chamber and slide housing 86, the top of which as customary is sealed by the slide (not shown) therein. When the die halves are closed, the slide housing 86, the die cavity 85, the runner 84 and the free space above the metal charge are completely evacuated through the exhaust channels 93, 94, communicating with manifold 101, passageway 102, port 103 leading into the vacuum line 38 controlled by valve 37. Thus, it is impossible for gases in slide housing 86 to get into contact with the molten metal during the casting.

In Figures 9 and 10, Figure 9 shows the ejector half and Figure 10 the cover half of a die block designed to cast a multiplicity of objects simultaneously. This particular die is designed to cast four castings simultaneously, i.e., has four die cavities each for producing a separate article which may be joined together by thin metal in the finished product so that they can be separated readily. The ejector half shown in Figure 9 has the exhaust channels 102 and 103 interconnected at their top by an exhaust channel 104 which, through the cylindrical openings 105 and 106 communicates with the ejector box 24 (Figure 1). The exhaust channels 102 and 103 through the vents 107 and 108 are connected with the runners 109 and 110, respectively. Runner 109 is provided with branches 115 and 116 communicating with the die cavities 111 and 112, respectively; runner 110 is provided branches 117 and 118 communicating with the die cavities 113 and 114, respectively. The runners 109 and 110 lead from a manifold runner 119' communicating with metal chamber 119 (Figure 10).

In Figure 9, the channels indicated by C are used for circulating a cooling fluid, usually water, through the die. Threaded opening I at the top of the die halves is adapted to receive an eye bolt for use in effecting removal of the die halves from the machine.

The cover half shown in Figure 10 has the packing P on all four sides held in place by packing retaining plates P'.

The cover half shown in Figure 10 has exhaust channels 102' and 103' designed to register (is congruent) with the exhaust channels 102 and 103, respectively, of the ejector half when the die is closed. The cover half also has a top exhaust channel 104' which registers with top channel 104 of the ejector half. Vents 121, 122, 123 and 124 connect each of the die cavities 111, 112, 113 and 114, respectively, with the exhaust channel 104' in the cover half. Vent 125 connects the die cavity 111 with the exhaust channel 103' and vent 126 connects the die cavity 114 with the exhaust channel 102'. In this way the runners 109, 110, the free space above the metal charge in metal chamber 119, and each of the die cavities 111, 112, 113 and 114 are thoroughly and completely vented through the exhaust channels formed by the registry of 103 and 103', 102 and 102', 104 and 104'. The exhausted air and gas from the runners, the free space above the molten metal, and the die cavities flow through the exhaust channels 102, 102', 103 and 103', and through the vents 107, 108, 121, 122, 123, 124, 125 and 126 into the exhaust channel 104, 104', which, through the openings 105, 106, communicate with the ejector box 24, which is evacuated through line 38, as shown in Figure 1.

In the modification shown in Figures 11 and 12, Figure 11 shows the ejector half and Figure 12 the cover half of the die block. In Figure 11 the runner 130', which communicates with metal chamber 130 (Figure 12), communicates through the runners 131 and 132 with the die cavity 133. In the cover half, shown in Figure 12, the die cavity is vented through the side wall vents 134 and 135 which lead into the exhaust channels 136 and 137, respectively. These side wall exhaust channels 136 and 137 lead into a top exhaust channel 138 connected through a vent 139 with the top of the die cavity 133,

Exhaust channel 138 is provided with an outlet channel 141 which communicates with the port 142 disposed at the parting line of the die block above the die cavity, with which port the vacuum line is connected.

It will be noted that in all modifications, complete and thorough venting of the metal chamber, the runners leading therefrom into the die cavity, the die cavity and all spaces communicating with the die cavity through which air or gas may enter thereinto, are in open and direct communication with the vacuum system, insuring substantially complete evacuation. Thus after the metal chamber has been evacuated removing air and gas from above the molten metal charge while the latter is stationary, the charge is then moved through the evacuated runners, into the evacuated die cavity while the vacuum is maintained thereon. This insures uniformly good castings, with consequent reduction in the number of rejects produced.

As noted, the exhaust channels and vents in Figures 8 to 12, inclusive, are shown enlarged for purposes of clarity of illustration.

It will be noted that the present invention provides a vacuum die casting procedure which is efficient, results in good quality castings and results in a marked reduction in the number of rejects. The process can be carried out in equipment simple in design and hence economical in first cost and to maintain and operate. It will be further noted the changes necessary to adapt existing high speed die casting equipment to vacuum die casting in accordance with the present invention are simple and relatively inexpensive. The invention is applicable to both the so-called "hot-chamber" and "cold-chamber" processes. "Hot-chamber" processes are used for casting zinc, tin and similar relatively low melting point alloys. "Cold-chamber" processes are used in the casting of aluminum, magnesium, brass and other such alloys. The invention is also applicable to the vacuum casting of other materials.

Since certain changes in carrying out the above-described die casting processes and in the equipment for its practice may be made without departing from the scope of this invention, it is intended that all matter contained in the above description, or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. The process of die casting involving the feed of molten material into a die cavity positioned between relatively movable die members and communicating with a substantially horizontally extending feed chamber having a greater volumetric capacity than that of said die cavity and provided with a feed port, which process comprises closing said die members to form said die cavity, thereafter introducing a charge of molten material through said feed port into said feed chamber, said charge being in amount to leave a free space above the charge in the portion of the feed chamber extending from the feed port towards the die cavity, slowly moving said molten material in said feed chamber toward said die cavity and away from said port while maintaining said free space in said feed chamber communicating with said die cavity and concurrently with said movement sealing said feed port, subjecting said die cavity and the communicating free space in said feed chamber to vacuum to remove from said die cavity and said communicating space air and gases, momentarily maintaining said molten material stationary in said feed chamber while subjecting said molten material through the said free space thereabove to said vacuum, thereafter moving said molten material into the die cavity while maintaining said vacuum thereon, interrupting said vacuum, thereafter moving said dies apart, and removing the resulting casting from the die.

2. The process of die casting in a die cavity positioned between relatively movable die members and communicating through a passageway with a substantially horizontally extending feed chamber having a greater volumetric capacity than that of said die cavity and provided with a feed port at the end of said feed chamber remote from said die cavity, which process comprises closing said die members to form said die cavity, introducing successive charges of molten material through said port into said feed chamber, each charge being introduced after the aforesaid closing of said die members and being of a volume such as to produce in said feed chamber a longitudinally extending free space above said charge for substantially the full length of said charge, slowly moving each charge in said feed chamber toward said die cavity and away from said port without introducing the charge into said passageway and without completely filling said feed chamber, thus leaving at all times during said feeding movement said free space in said feed chamber in contact with the charge of molten material and communicating with said die cavity, concurrently with said movement of the molten material in said feed chamber effecting sealing of said feed port, thereafter subjecting said die cavity, said passageway and the said free space in said feed chamber to vacuum to remove from said die cavity, said passageway and communicating free space, air and gases, momentarily maintaining said molten material stationary in said feed chamber while subjecting it to said vacuum through said free space, thereafter moving said molten material into the die cavity while maintaining said vacuum thereon, interrupting said vacuum, thereafter moving said dies apart and removing the resulting casting from the die.

3. The metal die casting process involving the use of a die cavity positioned between relatively movable die members communicating with a horizontally extending metal chamber having a greater volumetric capacity than that of said die cavity and provided with a feed port at the end of said metal chamber remote from said die cavity, which process comprises closing said die members to form said die cavity, introducing successive charges of molten metal through said port into said metal chamber, each charge being introduced after the aforesaid closing of said die members and being of a volume such as to produce in said metal chamber a horizontally extending charge with a free space thereabove and extending for substantially the full length of said charge, slowly moving each charge in said metal chamber toward said die cavity and away from said port without introducing the charge into said die cavity and without completely filling said metal chamber, thus leaving at all times during said feeding movement said free space in said metal chamber above the charge of molten metal and communicating with said die cavity, concurrently with said movement of the molten metal in said metal chamber effecting sealing of said feed port, thereafter subjecting said die cavity and the communicating space in said metal chamber to vacuum, momentarily maintaining said charge of molten metal in said metal chamber stationary while subjecting it to said vacuum, to remove air and gases from said die cavity, and said free space, thereafter moving said molten metal into the die cavity while maintaining said vacuum thereon, interrupting said vacuum, thereafter moving said dies apart and removing the resulting casting from the die.

4. A metal die casting process involving the use of relatively movable die members forming when closed a die cavity and communicating through at least one runner with a metal chamber having a greater volumetric capacity than that of said die cavity and extending in a generally longitudinal direction relative to said chamber and having in the end of said chamber remote from said die cavity a feed port for the introduction of the molten metal, which process comprises closing said die members to form said die cavity, introducing successive charges of molten metal through said feed port into said metal chamber, each charge being introduced after

the aforesaid closing of said die members and being of a volume such as to produce a longitudinally extending charge extending for substantially the full length of said chamber beyond said port, with a free space thereabove, slowly moving each charge in said feed chamber by means of a plunger toward said die cavity without introducing any substantial portion of said charge into the runner communicating with the die cavity and without completely filling said metal chamber so as to leave said free space at all times during said slow movement in the metal chamber above the charge of molten metal therein, said plunger in its continued slow movement effecting sealing of said feed port, subjecting said die cavity and the communicating runner and free space in said metal chamber to vacuum after said feed port is sealed to remove from said die cavity and said communicating free space and runner air and gases, maintaining the charge of molten metal in said metal chamber stationary during the initial period when the molten metal and feed chamber are subjected to vacuum, rapidly moving the charge of molten metal from the feed chamber into the die cavity while maintaining said vacuum on the die cavity, interrupting said vacuum, thereafter moving said dies apart, and removing the resulting casting from the die.

5. A metal die casting process involving the use of relatively movable die members forming when closed a die cavity and communicating through at least one runner with a metal chamber having a greater volumetric capacity than that of said die cavity and extending in a generally longitudinal direction relative to said chamber and having in the end of said chamber remote from said die cavity a feed port for the introduction of the molten metal, which process comprises closing said die members to form said die cavity, introducing successive charges of molten metal through said feed port into said metal chamber, each charge being introduced after the aforesaid closing of said die members and being of a volume such as to leave a free space in said metal chamber above the charge extending substantially the full length of said charge in said metal chamber, slowly moving each charge in said metal chamber by means of a plunger toward said die cavity without introducing any substantial portion of said charge into the runner communicating with the die cavity and without completely filling said metal chamber so as to leave said free space at all times during said slow movement in the metal chamber above the charge of molten metal therein, said plunger in its continued slow movement effecting sealing of said feed port, subjecting said die cavity and the communicating runner and space in said metal chamber to a vacuum within the range of 24" to 30" of mercury at the vacuum source after said feed port is sealed to remove from said die cavity said communicating space and runner air and gases, maintaining the charge of molten metal in said feed chamber stationary for from about one-eighth to one second during the initial period when said vacuum is applied, thereafter rapidly moving the charge of molten metal from the metal chamber into the die cavity while maintaining said vacuum on the die cavity, interrupting said vacuum after the complete charge has been introduced into the die cavity, thereafter moving said dies apart, and removing the resulting casting from the die.

6. Vacuum die casting apparatus comprising, in combination, a die block consisting of an ejector half and a cover half and defining when closed a die cavity between said halves with a portion of said die cavity in each half, a gasket on the marginal periphery of one of said halves of the die block which gasket, when the two halves are in abutment, provides a gas-tight seal at the meeting line between said halves, a feed chamber communicating with said cover half, a runner connecting said feed chamber with said die cavity, exhaust channels surrounding the sides and top of said die cavity, at least one vent leading from the die cavity to said exhaust channels, at least one additional vent leading from said runner to said exhaust channels, and means for placing said exhaust channels under vacuum.

7. Vacuum die casting apparatus, in combination; a die block comprising a cover half and an ejector half mounted for relative movement and adapted to be abutted to define a die cavity; a horizontally extending feed chamber having an inlet port at one end; a runner communicably connecting the other end of said feed chamber with said die cavity; a plunger for feeding successive charges of molten material within said feed chamber; a pressure cylinder for actuating said plunger to move each charge of molten material first slowly and concurrently to effect sealing of said inlet port, the said slow movement being effected while maintaining a free space above said charge, then maintaining said plunger stationary to maintain said charge stationary while subjected to vacuum through said die cavity, runner and said free space, and then injecting said charge rapidly into said die cavity while the vacuum is maintained thereon; and means for controlling the supply of pressure fluid and discharge of pressure fluid from said pressure cylinder to effect said initial slow movement of said plunger to thereafter maintain said plunger stationary and thereafter effect said rapid movement of said plunger and finally the return movement of said plunger; said means comprising a main valve for controlling flow of pressure fluid to and from said pressure cylinder, an electrically operated auxiliary valve to control the operation of said main valve either to supply pressure fluid to said pressure cylinder or to exhaust pressure fluid therefrom, a pilot valve communicating with said main valve, a second electrically operated valve, a third electrically operated valve, a line connecting said third electrically operated valve with said second electrically operated valve, a throttle valve in said line, said second and third electrically operated valves in one position effecting flow of pressure fluid from said main valve, by-passing said pilot valve through said third electrically operated valve, said throttle valve, said second electrically operated valve to the pressure cylinder to effect said slow movement of said feed plunger while maintaining said free space above the charge of molten material in said feed chamber during said slow movement, and in a second position of said second and third electrically operated valves effecting the flow of pressure fluid from said main valve through said third electrically operated valve, said throttle valve to said second electrically operated valve which prevents flow of said pressure fluid to said pressure cylinder, maintaining said feed plunger stationary and said third electrically operated valve in still another position thereof, effecting the feed of pressure fluid from said main valve through said third electrically operated valve to said pilot valve to position said pilot valve so that the flow therethrough from said main valve takes place directly to the pressure cylinder effecting said rapid actuation of said feed plunger through the feed chamber to effect the rapid introduction of the charge of molten material into the die cavity.

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