United States Patent

[11] 3,554,272

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[54] **DIE CASTING APPARATUS AND METHOD FOR CASTING ARTICLES FROM MOLTEN MATERIAL HAVING A PLURALITY OF HORIZONTALLY AND VERTICALLY MOVABLE DIES**
8 Claims, 12 Drawing Figs.

[52] **U.S. Cl.** **164/319,** 164/339, 164/131
[51] **Int. Cl.** **B22d 17/04**
[50] **Field of Search** .... 164/113, 120, 131, 137, 264, 303, 319, 321, 339, 347; 264/161; 18/(Spune vendor digest), 30NT, 30RU, 30WR, 42D

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Assistant Examiner—R. Spencer Annear
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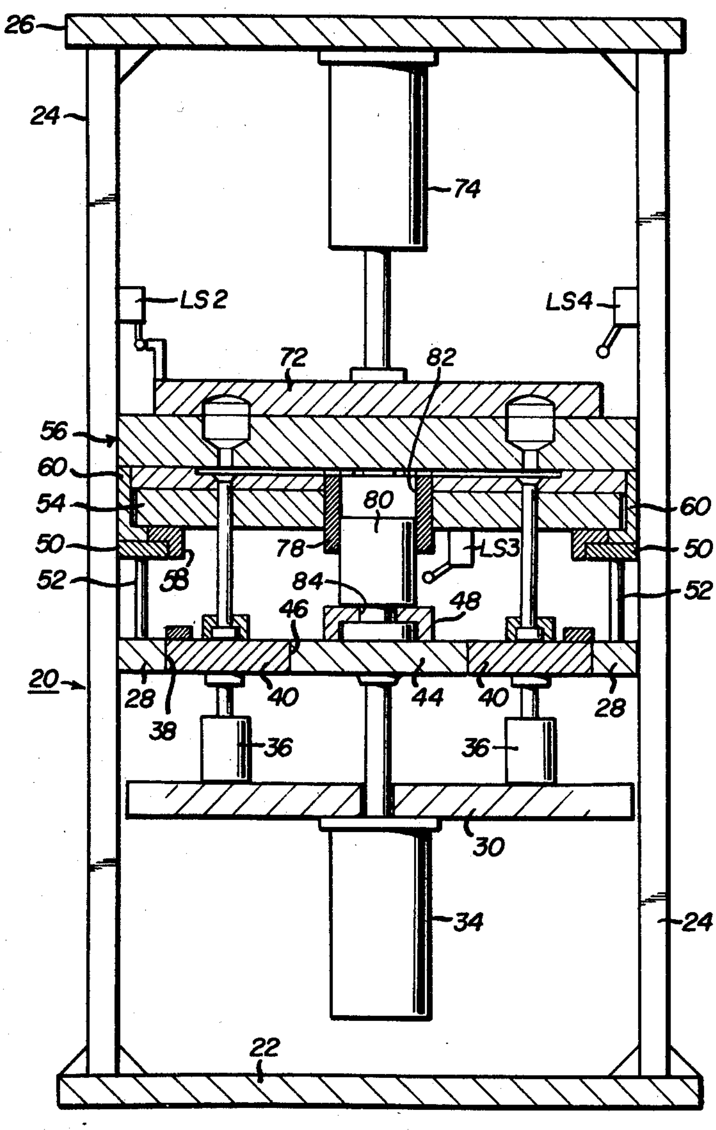
ABSTRACT: Die casting apparatus in which a plurality of separable die elements are relatively movable to each other to a die open position in which completed castings can be ejected simultaneously with the filling of the die with molten metal for the next subsequent casting operation. While the die is closed, pressure is applied to molten metal within the die cavities by pins to eliminate solidification shrinkage, the pins upon subsequent retraction creating weakened portions or voids in the solidified metal which are sheared during movement of the die elements to their open position to separate the completed castings from the major portion of the waste metal.



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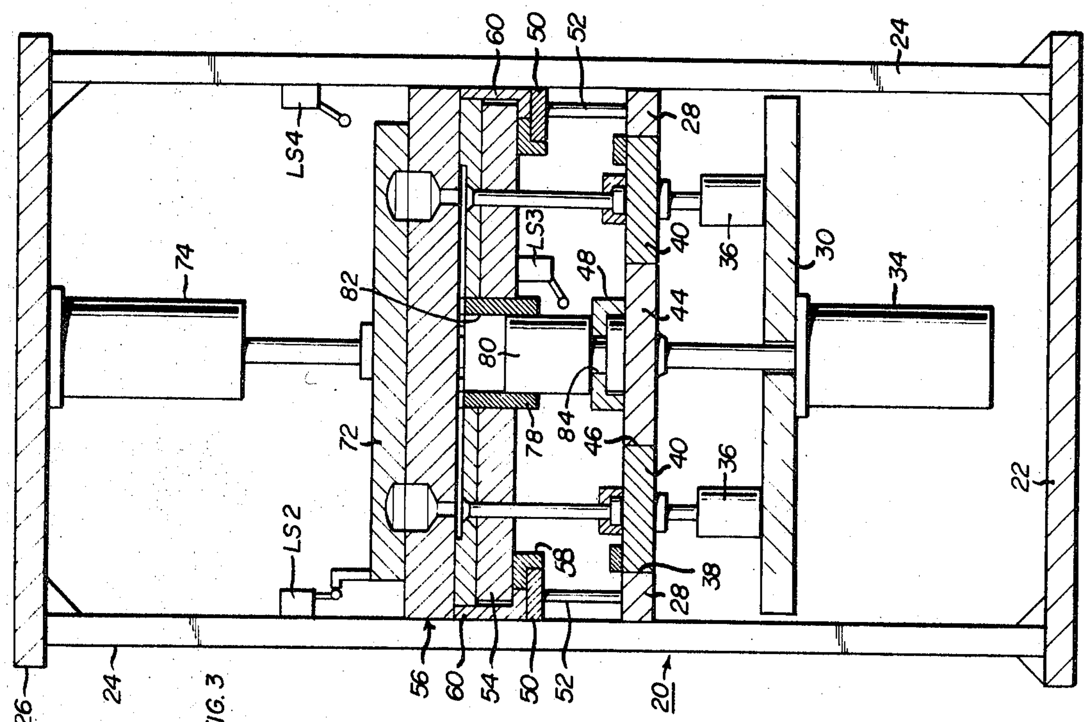

FIG. 3

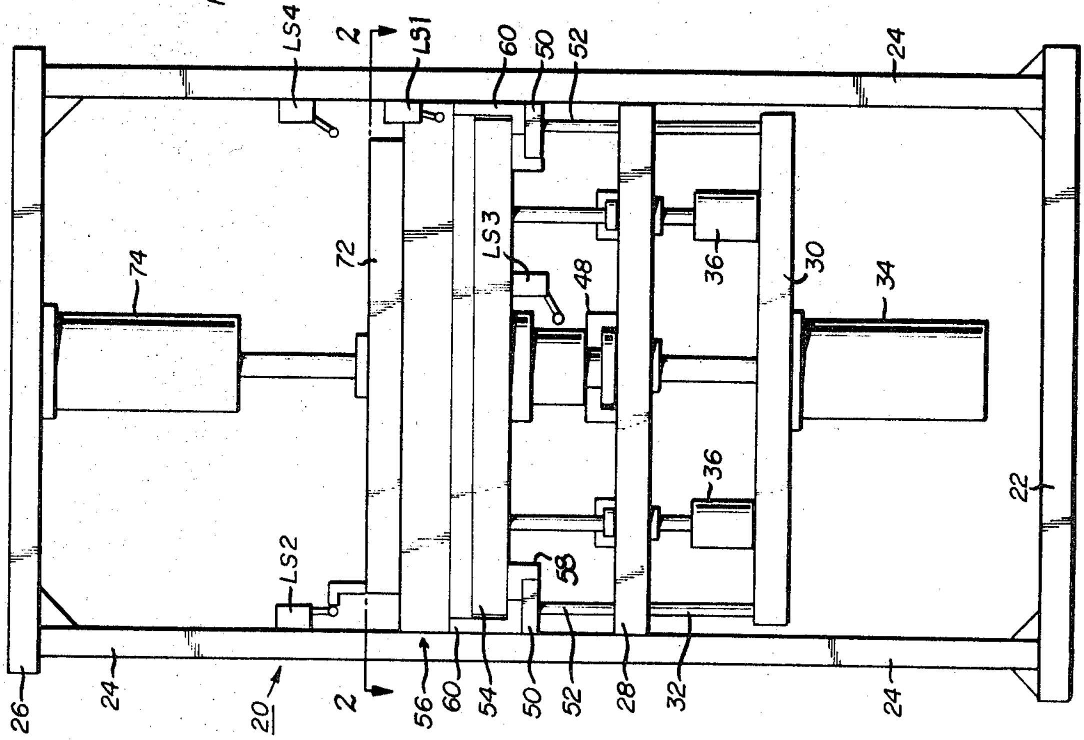

FIG. 1

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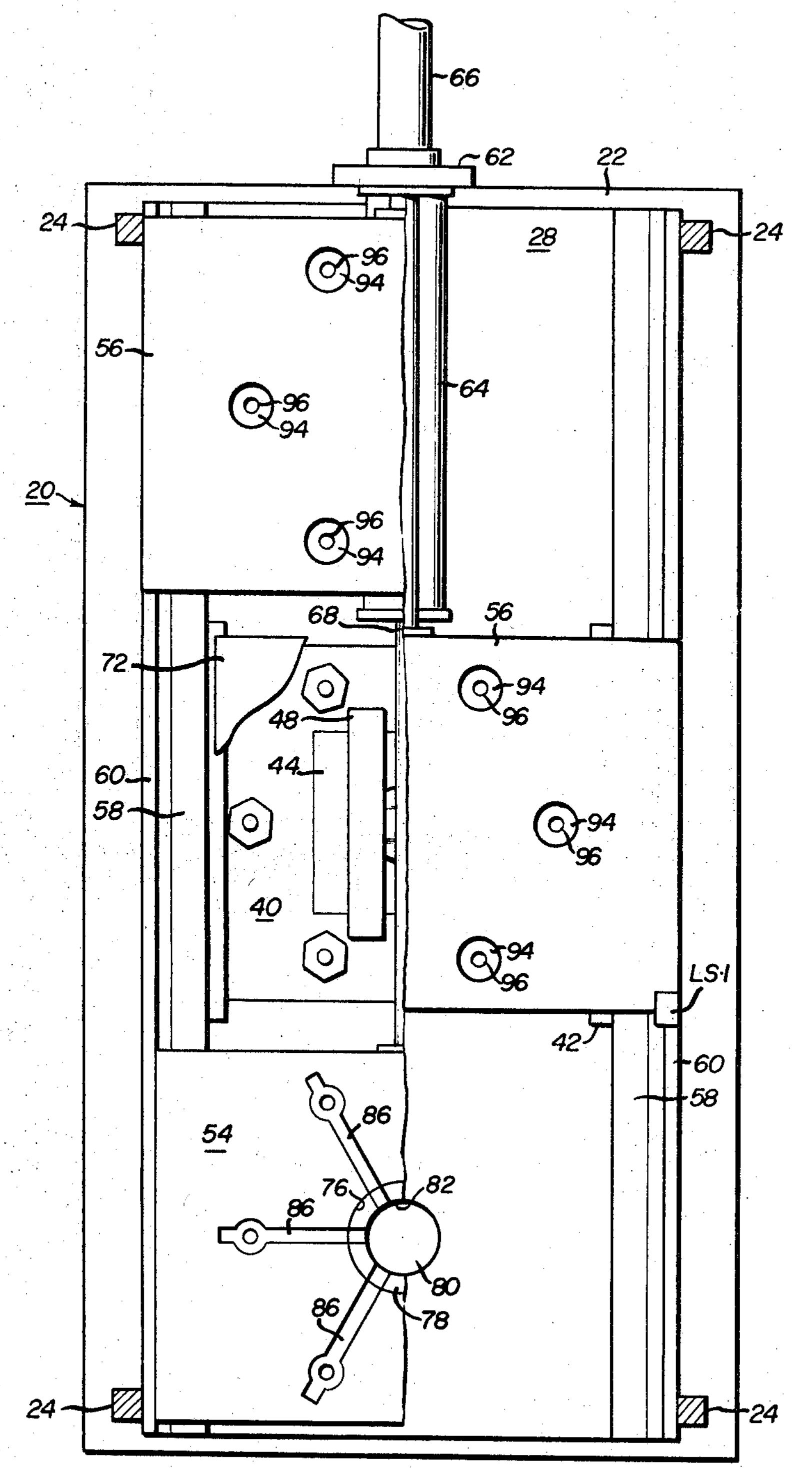

FIG. 2

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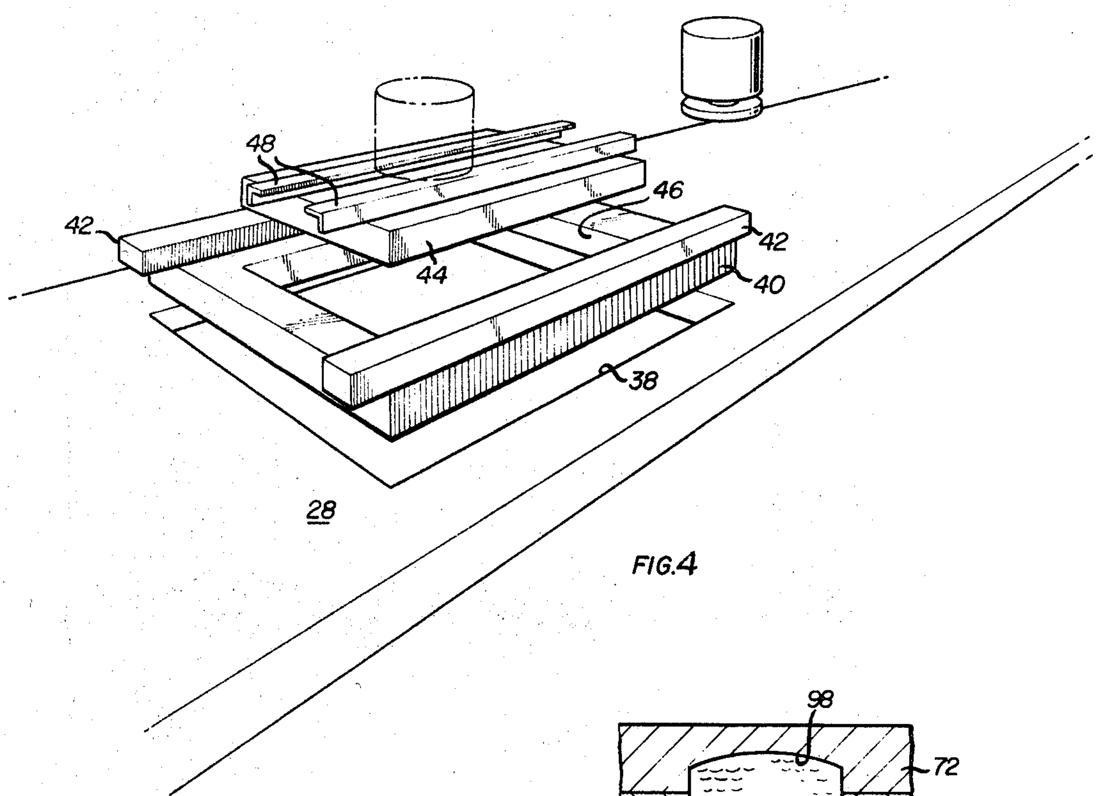

FIG. 4

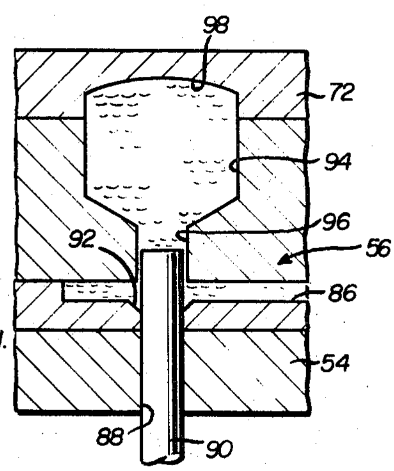

FIG. 5

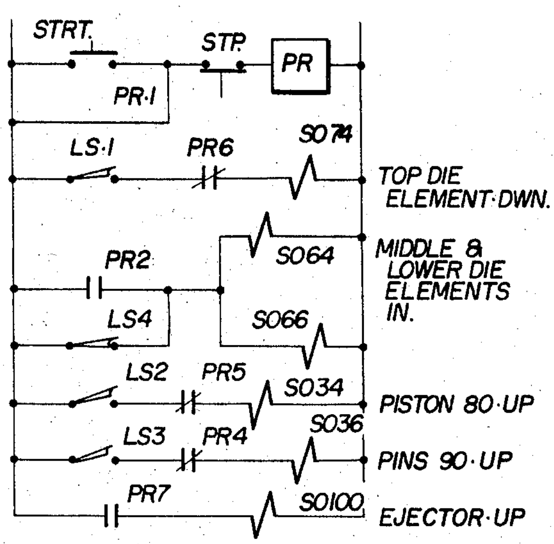

FIG. 12

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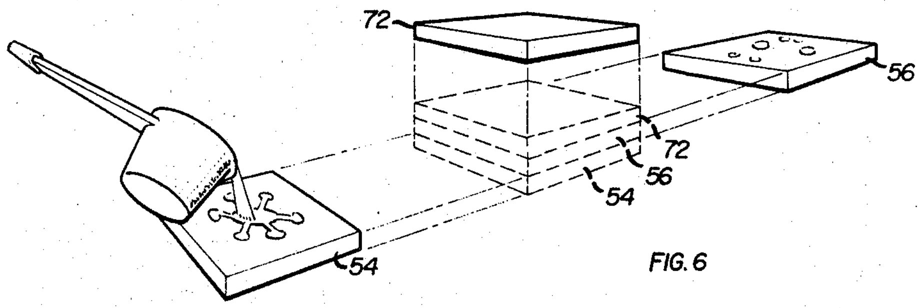

FIG. 6

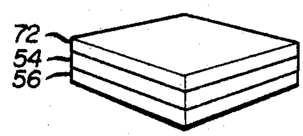

FIG. 7

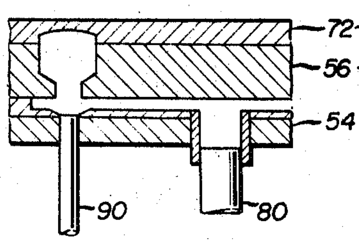

FIG. 8

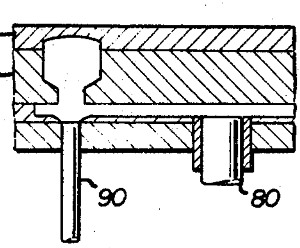

FIG. 9

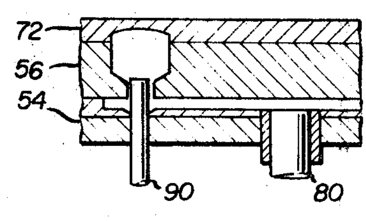

FIG. 10

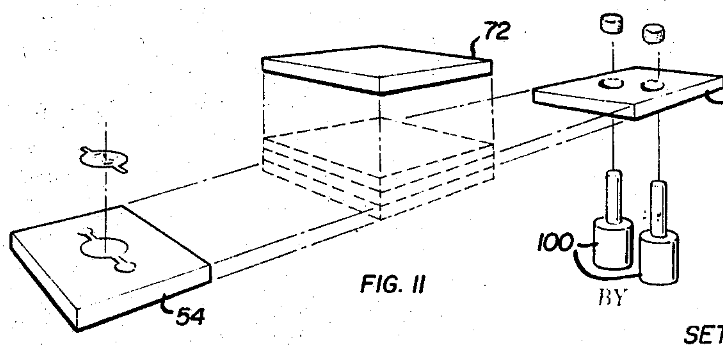

FIG. 11

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DIE CASTING APPARATUS AND METHOD FOR CASTING ARTICLES FROM MOLTEN MATERIAL HAVING A PLURALITY OF HORIZONTALLY AND VERTICALLY MOVABLE DIES

In certain of its aspects, the present invention represents an improvement to the die casting apparatus disclosed in my U.S. Pat. No. 3,120,038.

In the specific form of the invention disclosed in this application, a die casting apparatus includes three separable die elements which are located in a vertically stacked face-to-face engagement with each other when in their closed position. A plurality of individual die cavities are formed by opposed recesses in the engaged surfaces of the upper and middle die elements. The upper surface of the lower die element is formed with a plurality of grooves which radiate from a centrally located well in the lower of the three die elements. Vertical passages extend downwardly through the middle die element from the bottom of each of the individual die cavities to communicate with the grooves and thus place the cavities in communication with the well when the die is closed. A plurality of reciprocable pins are mounted in the lower die element in coaxial alignment with each of the passages in the middle die element.

With the well filled with molten metal, and the die elements in their closed position, a plunger which forms the bottom of the well is elevated, thereby forcing molten metal from the well through the grooves and passages into the die cavities. After the cavities are filled, the pins are elevated from their normal retracted position in which the upper end of the pin forms the bottom of the groove, upwardly into the coaxially aligned passage. The pins are elevated under relatively high pressure and pressure is applied to the pins throughout the period of solidification of the molten metal in the die cavities, thereby eliminating solidification shrinkage in the casting. After the metal is solidified, the pins are retracted, thereby creating voids in the solidified metal so that only a thin shell of metal connects the solidified metal in the passages to the solidified metal in the grooves.

The die is opened by elevating the upper die element, thereby exposing the upper portions of the completed castings. The middle and lower die elements are then separated by shifting the die elements horizontally in opposite directions relative to each other, this action shearing the thin shell of metal which connects the metal in the grooves to the metal in the passages. The exposed, completed castings are carried to one side of the machine by the retracting middle die element and are ejected. At the same time, the lower die element is moved to the opposite side of the machine, and the waste metal is ejected from the well and grooves, thereby exposing the well so that it may be filled with a fresh charge of molten metal while the previously completed castings are being removed from the opposite side of the machine.

In the disclosed form of the invention, it will be noted that the die cavities are formed in the middle and upper die elements, while the filling mechanism is carried entirely by the lower die element. By employing inserts to form the die cavities, the machine can be easily changed from one type of casting to another.

IN THE DRAWINGS

FIG. 1 is an end elevational view of one form of the present invention;

FIG. 2 is a cross-sectional view taken approximately on the line 2–2 of FIG. 1 showing, to the left of the centerline of the FIG. the machine which the middle and lower die elements in their die open position and, to the right of the centerline showing the middle and lower die elements in their die closed position;

FIG. 3 is a vertical cross-sectional view taken through the centerline of the machine;

FIG. 4 is an exploded perspective view of certain elements of the machine;

FIG. 5 is a detailed cross-sectional view of a die cavity during the solidification step;

FIGS. 6—11 are schematic views showing successive steps in the operation of the machine, FIG. 6 being a schematic perspective view of the lower, middle and upper die elements, showing the relative positions of the elements in their die open position in full line and in their die closed position in broken line;

FIG. 7 is a schematic view of the three die elements in their die closed position;

FIGS. 8, 9 and 10 are cross-sectional views illustrating successive steps in the cavity filling and pressure applying portions of the casting cycle;

FIG. 11 is a schematic perspective view, similar to FIG. 6, showing the ejection of castings and waste metal; and

FIG. 12 is a schematic electrical diagram of an exemplary form of control circuit for the machine of FIGS. 1 through 11.

The machine disclosed in the drawings has a fixed frame designated generally 20 which includes a base 22, a pair of vertical side frames 24 and a cross frame member 26 which extends between and joins the upper ends of the side frame members 24. A horizontal table 28 is fixedly mounted upon the side frame members to support various components of the die assembly for movement. At a central location, a support platform 30 is fixedly suspended from table 28 as by posts 32 to provide a mounting platform for the cylinders of a centrally located hydraulic motor 34 and a group of smaller hydraulic motors 36 which are located symmetrically about motor 34.

At a central location of platform 30, a rectangular opening 38 (see FIG. 4) is cut through table 28. A generally rectangular plate 40 slidably fits within opening 38 and is supported within the opening by a pair of elongate support blocks 42 which are fixed to the upper surface of plate 40 and project beyond the edges of opening 38 to rest upon the top of bed 38, thereby supporting plate 40 against downward movement through opening 38. The piston rods of motors 36 are attached to the lower side of plate 40, and upon actuation of motors 36, plate 40 can be elevated upwardly relative to table 28.

A second plate 44 is similarly slidably received within a rectangular opening 46 cut through plate 40. A pair of undercut guide tracks 48 are fixedly secured to the upper surface of plate 44 and extend beyond the edges of the plate to support plate 44 within opening 46, the extending portions of the tracks 48 resting on the upper surface of plate 40. The piston rod of motor 34 is connected to the bottom of plate 44, and motor 34 can be actuated to elevate plate 44 relative to plate 40 and bed 28.

Along each of the longitudinal sides of table 28, a slideway 50 is fixedly supported, as by a series of posts 52, to provide a sliding support for a lower die member 54 and a middle die member designated generally 56. Lower die member 54 is slidably supported upon tracks 50 as by shoes 58, while a pair of downwardly projecting feet 60 support the middle die element 56 for sliding movement upon tracks 50 at an elevation such that the lower surface of element 56 slidably engages the upper surface of lower die element 54 when the two elements are vertically overlapped with each other.

At one end of bed 28, a mounting plate 62 serves as a support for a pair of hydraulic motors 64 and 66 respectively. The piston rod 68 of motor 64 is connected to lower die element 54 and can be actuated to shift element 54 between a position in aligned vertical registry with plate 44 and the end of table 28 remote from mounting plate 62. The piston rod 70 of motor 66 is connected to the middle die element 56 and can shift die element 56 from between a position in vertical alignment with plate 44 and that end of bed 28 adjacent mounting place 62. When plates 54 and 56 are in alignment with plate 44, they are in alignment with each other and various passages, etc., to be described below in the die elements are lined up and in communication with each other.

In addition to the lower die element 54, and middle die element 56, the apparatus includes an upper die element 72 which is slidably guided by suitable means, not shown, in side frame members 24 for vertical reciprocatory movement under the control of a hydraulic motor 74 which is mounted upon the upper cross frame member 26.

Referring now particularly to FIGS. 2 and 3, lower die element 54 is formed with a central opening 76 within which is fitted a hollow cylindrical sleeve 78. A piston 80 is slidably received within sleeve 78 to close the lower end of the sleeve so that the interior of the sleeve defines a wall 82 for receiving a charge of molten metal. The lower end of piston 80 is formed with an annular groove 84 which, as best seen in FIG. 3, is received by guide tracks 48 when piston 80 is located above plate 44. Piston 80 is normally slidably supported upon the top of table 28 and slides back and forth with die element 54 as the die element is driven in reciprocation by hydraulic motor 64.

The upper surface of lower die element 54 is formed with a plurality of grooves 86 which radiate outwardly from well 82. Near the end of each groove 86 remote from well 82, die element 54 is bored as at 88 to slidably receive a plunger 90 whose lower end is slidably supported either upon bed 28 or plate 40, depending upon the position of die element 54 relative to the machine frame. The upper ends of bores 88 are preferably counterbored as at 92, and the upper end of plungers 90 are normally located at the lower end of counterbore 92, as illustrated in FIG. 3.

Middle die element 56 is formed with a series of recesses 94 each of which defines a main portion of a die cavity. A vertically extending passage 96 is bored through middle die element 56 to extend downwardly from the bottom of recess 94 through die element 56. Recesses 94 and passages 96 are so located that when the die elements are in their die closed position, each passage 96 is coaxially aligned with a pin 90 so that when the pins 90 are elevated from their FIG. 3 position, the upper end of the pin 90 is projected upwardly into the passage 96. Thus, the number of die cavity defining recesses 94 corresponds to the number of radial grooves 86 in lower die element 54.

Upper die element 72 is formed with a series of downwardly opening recesses 98, each of which defines a portion of an individual die cavity. When the die elements are in their closed position, each of the recesses 98 is in communicating alignment with a recess 94 in middle die element 56, the recesses 94 and 98 cooperating to define a closed die cavity.

Although the die cavities are disclosed as being formed directly in die elements 56 and 72, it will be apparent that the die elements may be provided with enlarged openings into which die cavity defining inserts may be mounted so that the machine can readily be converted for the production of different castings.

The operation of the machine is best understood by reference to FIGS. 2 and 6 through 12 inclusive of the drawings. FIG. 2 is a plan view of the machine with die elements 54, 56 and 72 indicated in their die open position on the left-hand side of FIG. 2 and shown in their die closed position on the right-hand side of FIG. 2. The relationship of the three die elements to each other in their die open position is also schematically illustrated in FIG. 6, the full line showing being that of the die open position with the respective die closed positions indicated in broken line.

As explained above, die elements 54 and 56 are driven between their respective die open and die closed positions by actuation of motors 64 and 66 respectively, while die element 72 is moved between its open and closed position by motor 74. When die element 54 is at its open position, it is located at one end of the machine frame with well 82 fully exposed and readily accessible so that a charge of molten metal can be poured into the well, as indicated in FIG. 6. The lower end of well 82 is closed by piston 80. The dimensions of the well are sufficient to receive a charge of metal having a volume sufficient to fill all of the die cavities, as well as the communicating passages between the cavities and well 82.

Control of the operation of motors 34, 36, 64, 66, 74 described above and of an ejector motor 100 may be performed automatically by means of an electrical control circuit, such as that illustrated in FIG. 12.

Each of the aforementioned hydraulic motors is connected to the high pressure side and to the sump of a hydraulic pressure source through a four-way reversing valve operable in one position to cause the piston rod of the motor to extend and operable in the other position to retract the piston rod of the associated motor. The hydraulic connections of such a system are well known and completely conventional, and hence have not been illustrated in the drawings.

Each of the four-way reversing valves is preferably of the type wherein the valve is normally maintained in one position by a spring and is shifted to the opposite position by means of an electrical solenoid. Solenoid actuated reversing valves of this type are conventional and commercially available.

In the electrical diagram of FIG. 12, the six motor controlling solenoids are identified with a prefix SO followed by the reference numeral indicating that particular motor which they control. Thus, solenoid SO 74 identifies the solenoid which controls operation of motor 74, solenoid SO 64 identifies the solenoid controlling operation of motor 64, etc. The printed legend at the right of the diagram of FIG. 12 specifies the position of the element controlled by the respective motor when the solenoid is energized. Thus when solenoid SO 74 is energized, the top or upper die element 72 is at or being driven toward its die closed position. The sequence of operation of the various motors is controlled by a motor driven cam timer in which various switches are automatically opened and closed at predetermined time intervals by associated cams. Such timers are well known and commercially available.

At the beginning of the cycle, all of the solenoids of the diagram of FIG. 12 are deenergized, thus conditioning motors 64, 66 and 74 to position die elements 54, 56 and 72 in the positions shown in FIG. 6, conditioning motors 34 and 36 to locate piston 80 and pins 90 in their retracted position and locating the ejector motor 100 in its nonoperative position.

The first step in a casting cycle, with the parts in the positions just described, is that of pouring a charge of molten metal into well 82. The volume of metal in this charge is sufficient to fill all of the die cavities and the various communicating passages.

Upon the pouring of the molten metal into the well, an automatic casting cycle is initiated by pressing the start button of the circuit of FIG. 12 to energize the timer of programmer PR, thereby starting the timed sequence of opening and closing of various contacts to be described below. The first step in this sequence is to cause the programmer to close a first cam controlled switch PR-1 which bypasses the start button to lock the programmer in to drive through a complete cycle.

The first step in the actual casting cycle finds timer control contacts PR-2 being closed to simultaneously energize solenoids SO 64 and 66 to cause motors 64 and 66 to stroke respectively in a direction driving lower die element 54 and middle die element 56 inwardly to their die closed positions. Upon arrival of middle die element 56 at its die closed position, middle die element 56 engages the striker of a limit switch LS-1 to close the contacts LS-1 of FIG. 12 to thereby energize solenoid SO 74. Energization of solenoid SO 74 causes motor 74 to drive upper die element 72 to its die closed position. At the conclusion of this step the three die elements are in their die closed position in the vertically stacked relationship schematically shown in FIG. 7.

When upper die element 72 reaches its die closed position, it closes contacts LS-2 of a second limit switch, this action energizing solenoid SO 34 to cause motor 34 to drive piston 80 upwardly, thereby forcing molten metal out of well 82 outwardly along grooves 86 and thence upwardly through passages 96 into the various die cavities.

After piston 80 has been driven upwardly a predetermined distance, the striker of a third limit switch LS-3 is engaged. The distance of travel of piston 80 before engaging limit switch LS-3 is selected in accordance with the volume of metal necessary to completely fill all of the die cavities and connecting passages. Pressure is continued to be applied to motor 34 so that the piston continues to exert pressure upon the molten metal within the cavities.

Upon the engagement of the striker of limit switch LS-3, contacts LS-3 of the electrical diagram of FIG. 12 are closed to energize solenoid SO 36, thereby causing motors 36 to drive the forging pins 90 upwardly from the position shown in FIG. 9 toward that shown in FIG. 10.

Referring to FIG. 5, it will be seen that a slight clearance is provided between pin 90 and the walls of passage 96. This clearance is so small that while pins 90 can easily enter passage 96, little, if any, pressure applied by the upward movement of pin 90 toward the die cavity is led past the side of the pin, so that for all practical purposes, the pressure applied by pin 90 is exerted entirely upon the molten metal within the die cavity.

The purpose of this application of pressure, which is maintained throughout the transition of the metal within the die cavity from its liquid to its solid state, is to eliminate porosity caused by solidification shrinkage. This particular problem is discussed in greater detail in my U.S. Pat. No. 3,120,038.

The application of pressure by pins 90 to the solidifying metal in the various die cavities is maintained for a predetermined period of time, at the conclusion of which timer control contacts PR 4 and PR 5 are opened to respectively deenergize solenoids SO 34 and SO 36, thereby causing pins 90 and piston 80 to be retracted to their original position.

Shortly after the timer opens contacts PR 4 and PR 5, another set of normally closed timer control contacts PR 6 are opened to deenergize solenoid SO 74, thereby causing motor 74 to retract upper die element 72 to its die open position. When upper die element 74 reaches its die open position, it engages the striker of a limit switch LS 4 to open contacts LS 4 of FIG. 12 to thereby deenergize solenoids 64 and SO 66. This latter action causes motors 64 and 66 to retract the middle and lower die elements toward their die open position.

Prior to the separation of die elements 54 and 56, the solidified metal in well 82 and passages 86 is connected to the solidified metal within the die cavities via that metal within passage 96. Referring to FIG. 5, it is seen that when pin 90 is in its fully extended position, it substantially fills the interior of passage 96. Because pins 90 are not retracted until a point in time after which all of the metal has been solidified, the retraction of pins 90 leaves a void within passage 96, and hence just prior to the separation of die elements 54 and 56, only a relatively thin shell of metal extends across the plane at which the opposed surfaces of die elements 54 and 56 are located. This relatively thin shell of metal is readily sheared by the relative sliding movement between die elements 54 and 56 as they separate during the beginning of their movement toward their retracted position. This action thus separates the castings in the die cavity from the waste metal in passages 86 so that the plurality of castings can be individually removed from the die.

The final operation of the timer is to temporarily energize timer control contacts PR 7 which momentarily energize solenoid 100 to cause ejector motor 100 to drive upwardly to eject the castings from their individual cavities after die element 56 has reached its fully retracted position. At the conclusion of the cycle, timer control contacts PR 1 are opened, thereby stopping operation of the programmer.

While one embodiment of the invention has been described in detail, it will be apparent to those skilled in the art that the foregoing embodiment may be modified. For example, rather than have the table bed 28 extend the entire length of the machine, it could easily be shortened and suspended from die element 54 to move with the die element. While only two horizontally reciprocable die elements have been disclosed, the number of such elements may be increased i.e. for example, die element 56 might be split in half with the respective halves being capable of being withdrawn transversely of the disclosed path of movement of die element 56. Further, pressure applying plungers for applying pressure to molten metal in the die cavity may be added as desired in accordance with the configuration of the particular casting. Therefore, the foregoing description is to be considered exemplary rather than limiting, and the true scope of the invention is that defined in the following claims.

I claim:

1. Die casting apparatus comprising a plurality of separable die elements, means for moving said die elements between a die open position wherein said die elements are remote from each other and a die closed position wherein said die elements are in face-to-face engagement with each other, a first of said die elements having a molten metal receiving well therein and a plurality of grooves in its upper surface radiating from said well and a second of said die elements having a lower surface located in face-to-face engagement with said upper surface of said first die element when said die elements are in their die closed positions, means defining a plurality of individual die cavities in some of said die elements including said second die element with each cavity communicating with one of said grooves in said first die element at a location remote from said well when said die elements are in their die closed position, first pressure means operable when said die elements are in their die closed position to force molten metal from said well through said grooves to fill said die cavities and second pressure means operable subsequent to the filling of said die cavities by said first pressure means to substantially isolate the cavities from said well and to apply pressure to molten metal within each die cavity until the metal within the cavity has entirely solidified; said first and said second die element being mounted for closing and separating movement along parallel longitudinal axes intersecting the longitudinal axis of movement of the other die elements.

2. Die casting apparatus as defined in claim 1 wherein said second pressure means comprises a plurality of pressure applying members each movable from an initial normally maintained position transversely in one direction across one of said grooves and the plane of engagement between said upper and said lower surface to apply pressure to molten metal in the associated cavity and movable in the opposite direction back to its original position after solidification of the molten metal to form an internal void constituting a weakened section in the solidified metal extending across said plane of engagement, said movement of said first and second die elements along overlapping parallel axes to move said die elements from their closed position to their open position being operable to shear the metal across said weakened sections, thereby separating the castings in said cavities from the waste metal in said well and said grooves.

3. Die casting apparatus as defined in claim 1 wherein said first of said die elements is formed with a plurality of vertical bores therein, each of said bores extending downwardly from one of said grooves, said second of said die elements having a plurality of vertical passages therein extending upwardly from its lower surface in respective coaxial alignment with said bores when said die elements are in their die closed position and establishing communication between the respective grooves and die cavities, each of said second pressure means comprising a pin slidably mounted in one of said bores, and pressure operable means for driving the pin from a retracted position at the bottom of its associated groove upwardly into the associated passage to apply pressure to molten metal within the communicating cavity.

4. Die casting apparatus comprising a frame, a plurality of die elements mounted upon said frame for movement between an open position wherein the individual die elements are separated from each other and a die closed position wherein said elements are located in vertical face-to-face abutment with each other, some of said die elements being mounted for movement along parallel axes and the remainder of said die elements being mounted for movement along an axis normal to said parallel axes, the lowest of said die elements having means defining a molten metal receiving well therein exposed to receive a charge of molten metal when said elements are in their die open positions the remaining die elements having passage means therein cooperable to define a plurality of die cavities in communication with said well when said elements are in their die closed position, first means operable when said elements are in their die closed position to transfer molten metal from said well to said die cavities, and second means

operable when said elements are in their die closed position and said cavities have been filled with molten metal to cut off communication between said well and said cavities and to apply pressure to molten metal in said die cavities until said molten metal has solidified.

5. Die casting apparatus comprising a frame, a plurality of die elements mounted upon said frame for movement between respective die open positions wherein the individual die elements are positioned upon said frame in relatively remote locations from each other and die closed positions wherein said elements are located in vertically stacked face-to-face abutment with each other, said die elements including a lower die element having means defining a molten metal receiving well therein exposed to receive a charge of molten metal when said elements are in their die open positions, said lower die element having a plurality of grooves in its upper surface radiating from said well, a middle die element and an upper die element having recesses in the opposed surfaces thereof cooperable to define a plurality of die cavities, passage means extending downwardly through said middle die element from each die cavity to communicate with one of said grooves when said elements are in their die closed position, first means for elevating said upper die element from its die closed position to its die open position wherein said upper die element is clear of castings in said middle die element, and second means operable when said upper die element is in its die open position to shift said middle and lower die elements horizontally to opposite ends of said frame.

6. Die casting apparatus as defined in claim 5 further comprising means operable when said die elements are in their closed position to transfer molten metal from said well through said grooves and passages to fill said die cavities, pin means in said lower die element, means operable subsequent to the filling of said cavities to project said pin means from said lower die element into said passages and to retract said pin means into said lower die element subsequent to the solidification of molten metal in said grooves, passages and die cavities.

7. Die casting apparatus comprising a frame, a first die element mounted upon said frame for movement between a die closed position and a die open position, means defining a well in said first die element adapted to receive a charge of molten metal when said first die element is in its die open position, means defining a groove in the upper surface of said first die element extending laterally from said well, a second die element mounted on said frame for movement along an axis parallel to the axis of movement of said first die element between a die open position wherein said second die element is remote from said first die element and a die element is in seated face-to-face engagement with the upper surface of said first die element, said second die element having a recess in its upper surface defining at least a portion of a die cavity and a passage extending downwardly through said second die element from said recess to place said recess in communication with said groove when said elements are in their die closed positions, a third die element mounted upon said frame for vertical movement between a die open position wherein said third die element is remote from said first and second die elements and a die closed position wherein the lower surface of said third die element is in seated face-to-face engagement with the upper surface of said second die element, said third die element having a recess in its lower surface cooperable with the recess in said second die element when said elements are in their die closed position to define a closed die cavity, first plunger means operable when said elements are in their die closed position to force molten metal from said well through said groove and passage into said die cavity to fill said cavity, and second plunger means having a pin mounted in said first die element and operable upon filling of said die cavity to project said pin upwardly through said groove into said passage to apply pressure to molten metal in said cavity until the molten metal has solidified.

8. Die casting apparatus as defined in claim 7 wherein said second plunger means further comprises means to withdraw said pin into said first die element subsequent to the solidification of said molten metal to thereby create a void defining a weakened section connecting the solidified metal in said groove to the solidified metal in said passage.