METHOD AND APPARATUS FOR HIGH-PRESSURE PERMANENT MOLDING

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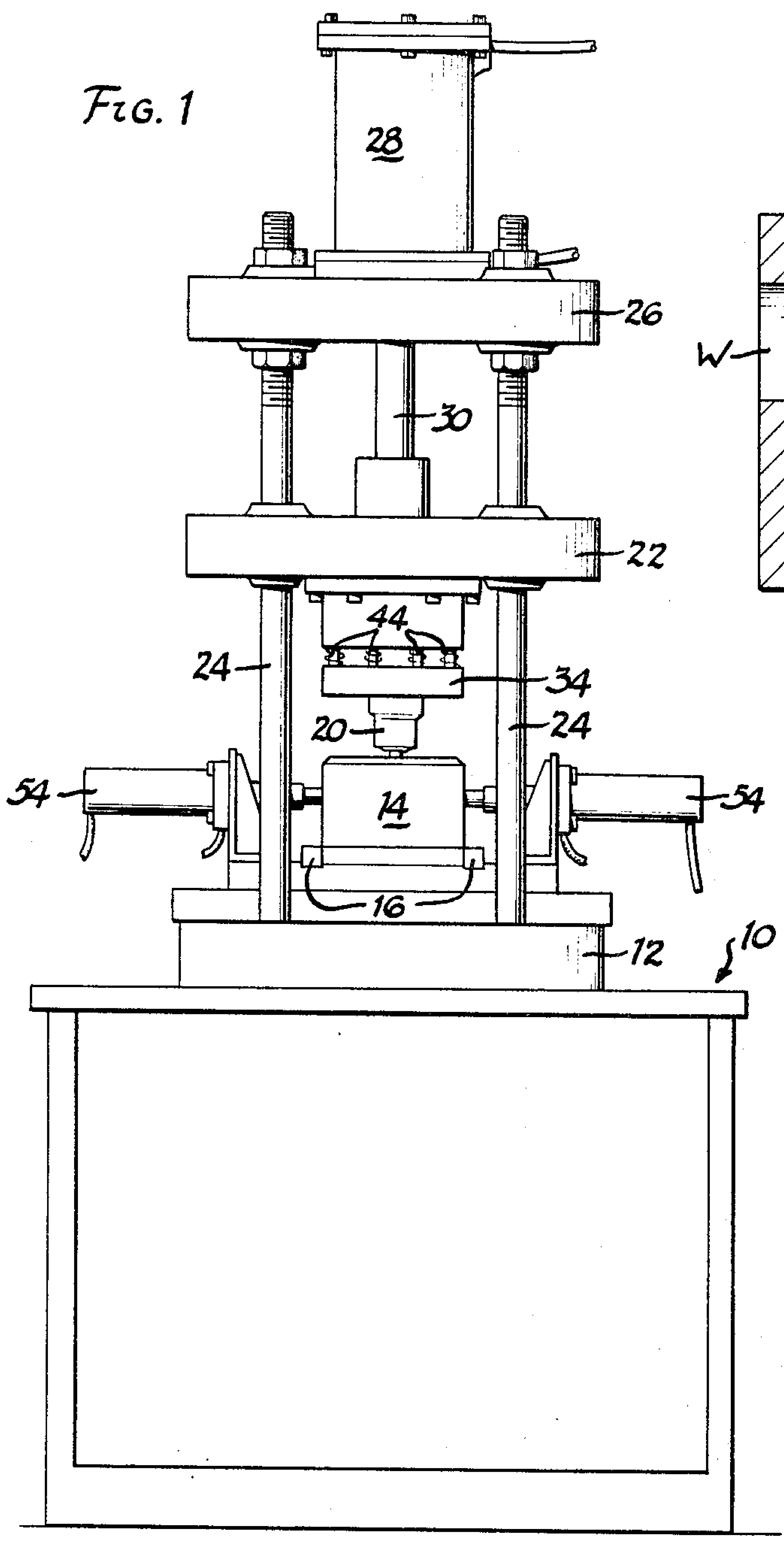
FIG. 1



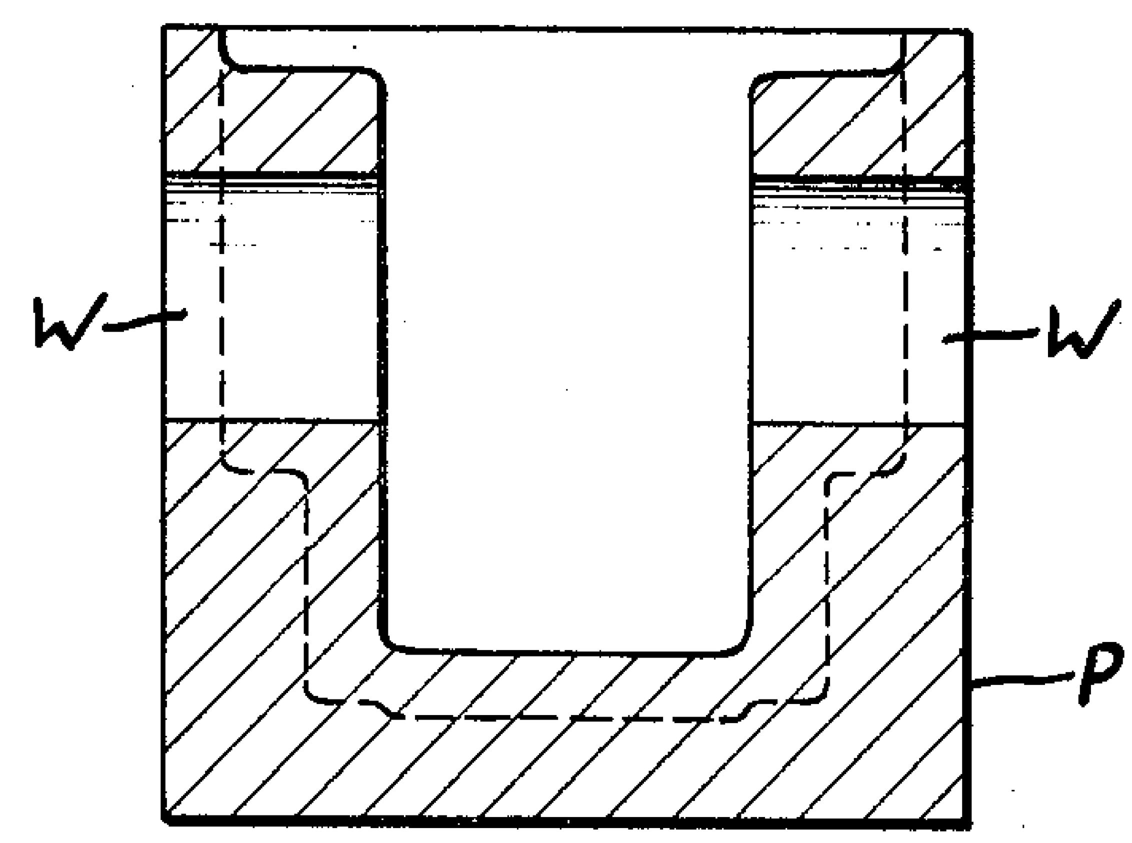


FIG. 5

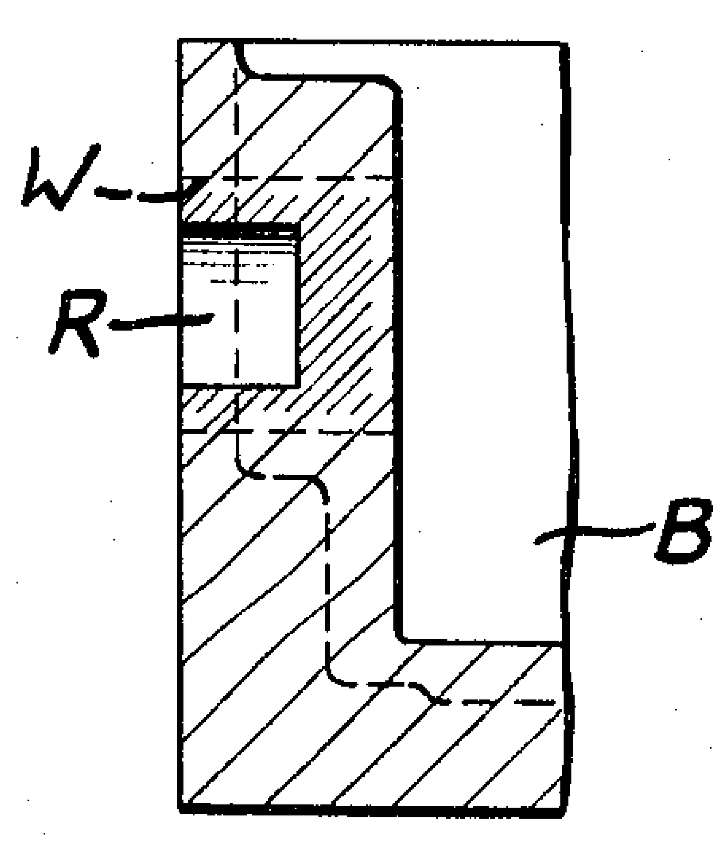


FIG. 6

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METHOD AND APPARATUS FOR HIGH-PRESSURE PERMANENT MOLDING

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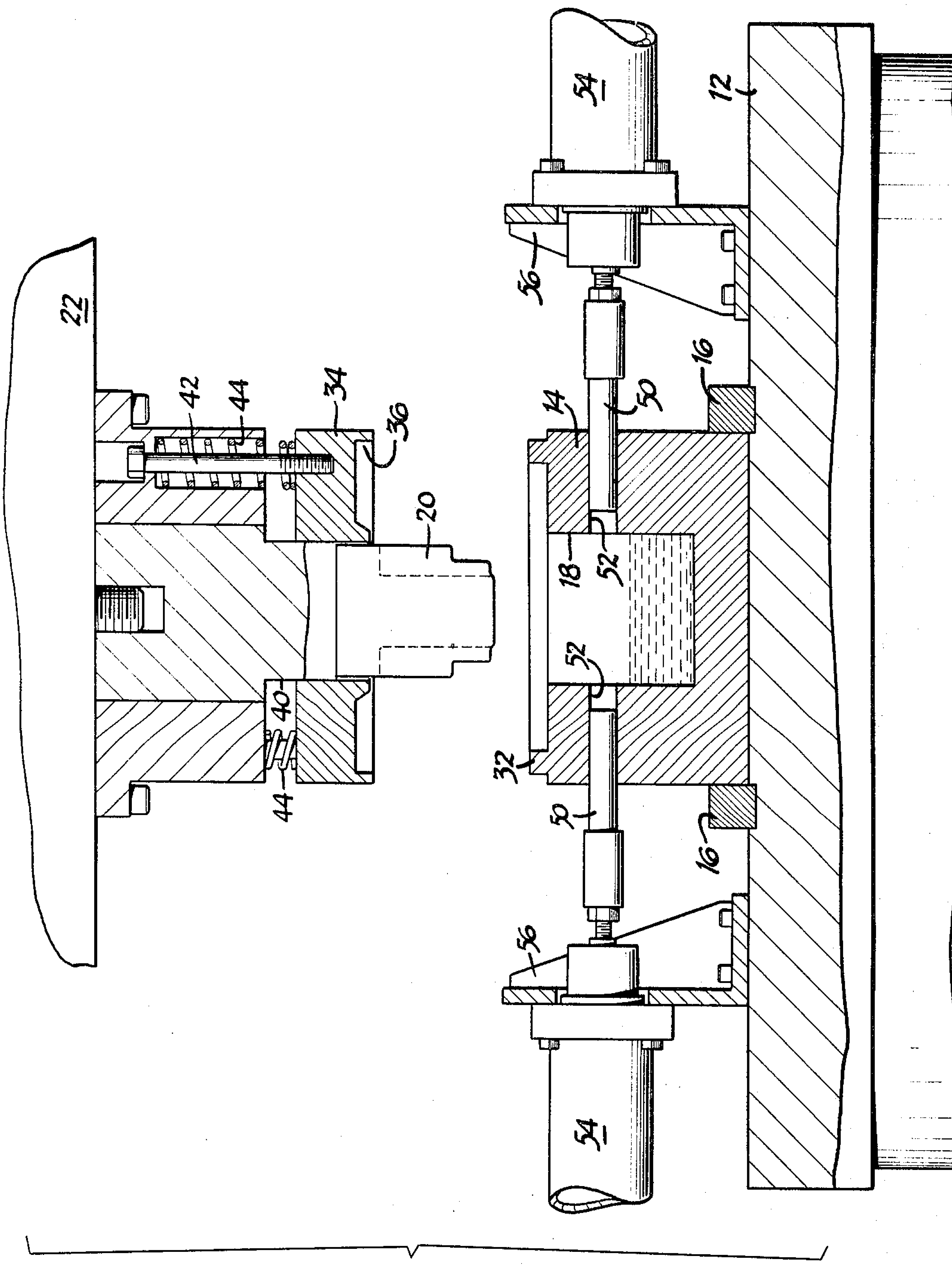

FIG. 2

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METHOD AND APPARATUS FOR HIGH-PRESSURE PERMANENT MOLDING

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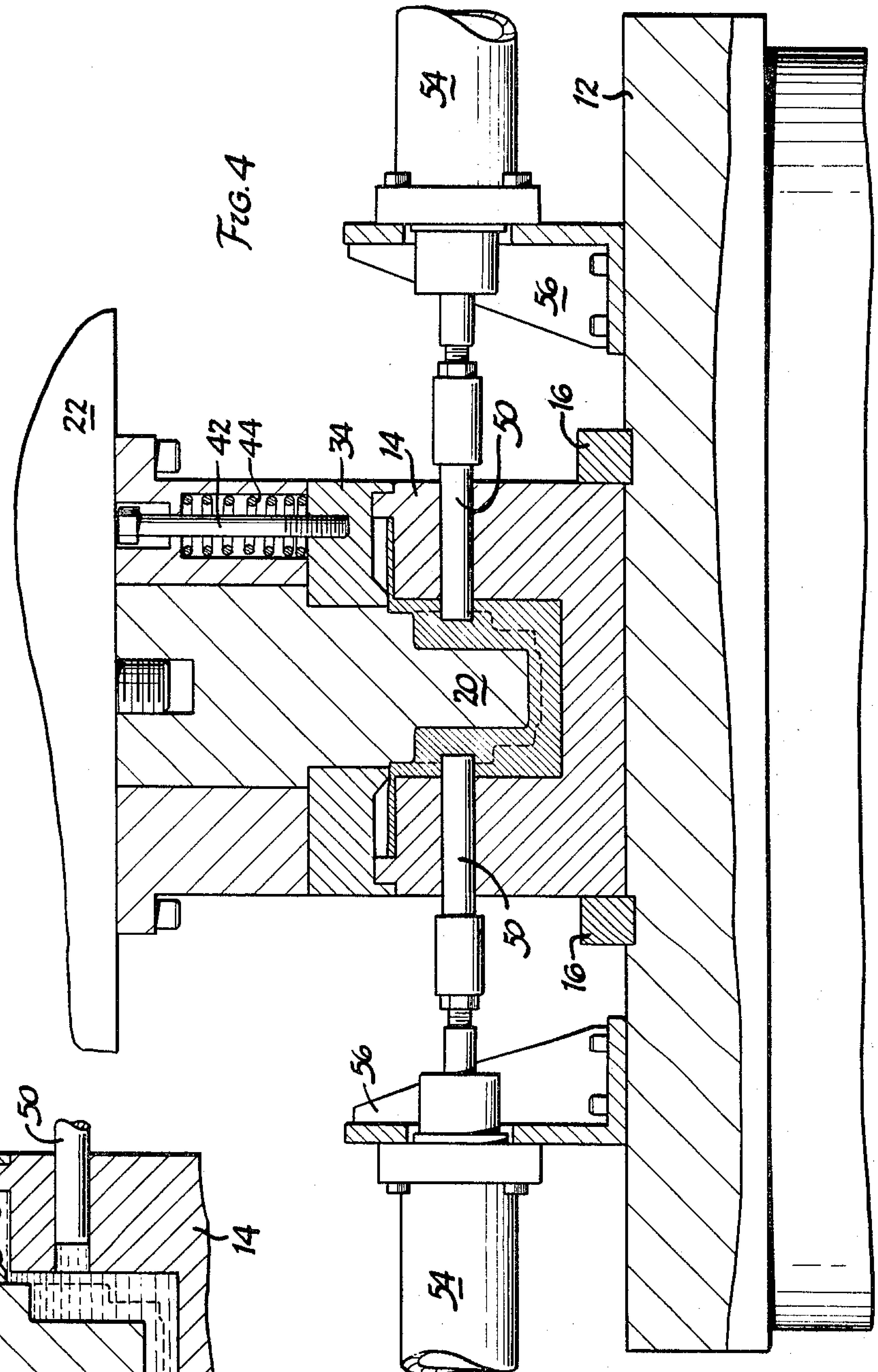

FIG. 4

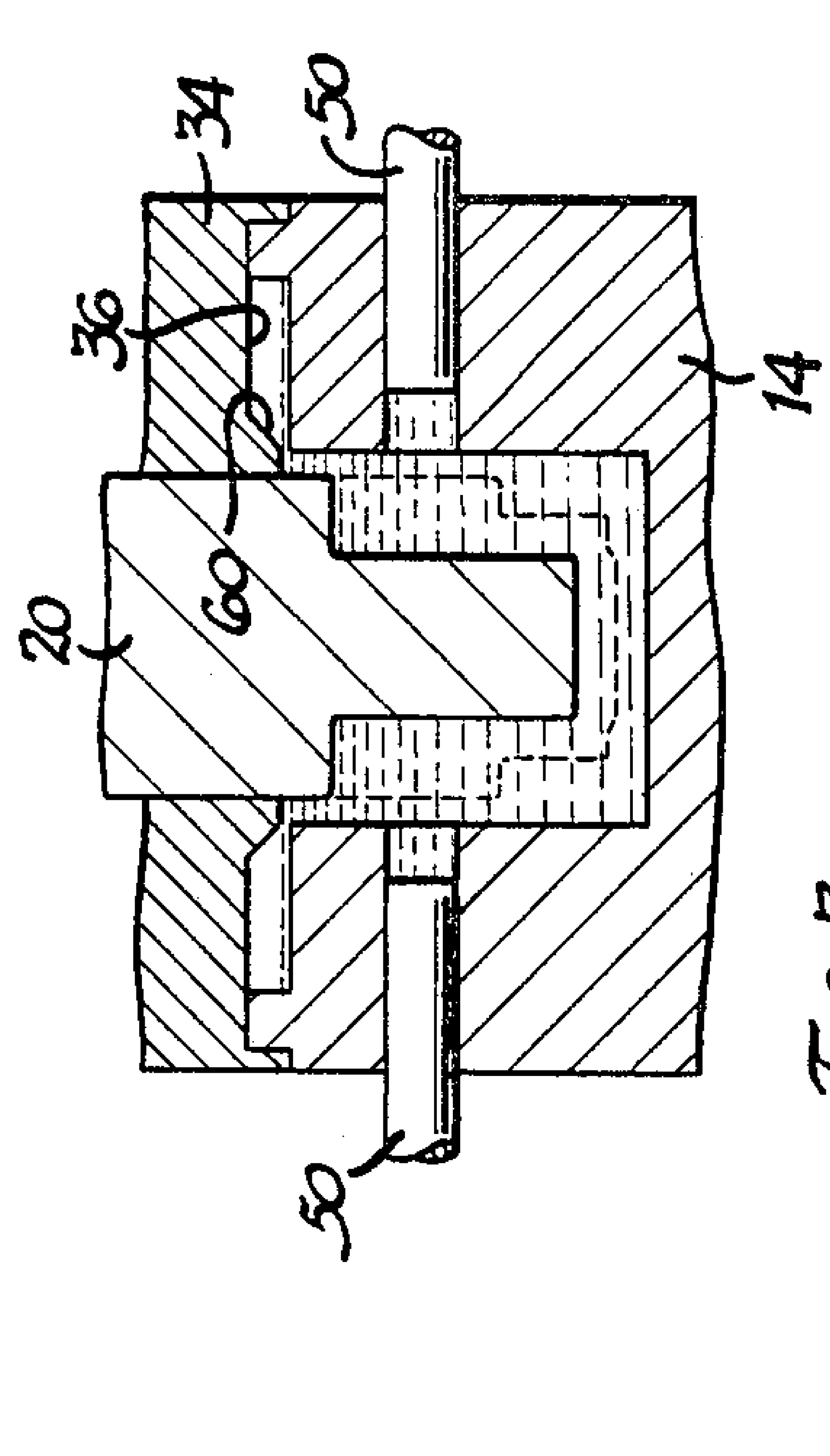

FIG. 3

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METHOD AND APPARATUS FOR HIGH-PRESSURE PERMANENT MOLDING

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Filed Sept. 18, 1963, Ser. No. 309,692
The portion of the term of the patent subsequent to Feb. 4, 1981, has been disclaimed
8 Claims. (Cl. 164—120)

ABSTRACT OF THE DISCLOSURE

Method and apparatus for the production of castings by means of which internal voids or porosity due to solidification shrinkage is eliminated and an improved grain structure is obtained by mechanically feeding excess molten metal under pressure into a closed die cavity during solidification of molten metal in the cavity. The feeding of excess metal is directed to those regions of the casting which normally would be the last to solidify.

Specific reference is made to my United States Patent No. 3,120,038.

The term "solidification shrinkage" as employed in connection with the molding of metal articles refers to the substantial reduction in volume which occurs in the metal as the metal changes state from a molten liquid form to the solid form. As employed in this application, solidification shrinkage is to be distinguished from ordinary thermal contraction and, for most metals, the solidification shrinkage of the metal as it changes from liquid to solid state is of a magnitude such that the thermal contraction of the metal as it subsequently cools in the solid state is comparatively negligible.

The manner in which molten metal cools in a mold is, for substantially all castings, non-uniform; relatively thin sections of casting cooling before the thicker sections, and the thicker sections cooling first near the surface of the casting and last at the portions most distant from the surface. As the molten metal changes from its liquid state to a solid state, a substantial reduction in the volume of the metal at the cooled region occurs. Because of the reduction in the volume occupied by the metal in regions of the casting which solidify first, molten or liquid metal from those regions of the casting which have not yet solidified tend to flow toward those regions which have already solidified with the result that there is a tendency to form a void within the casting in that region which is the last to solidify.

In the case of piston castings, for example, the skirt and top of the piston are usually relatively thin sections as compared to the wrist pin bosses formed interiorly of the skirt. The relatively thin skirt and head tend to cool before the interior of the wrist pin bosses and thus in a simple piston structure, voids occasioned by solidification shrinkage tend to occur in the wrist boss portions. Since these portions are subsequently machined to receive the wrist pin, it is especially desirable that no voids be present in this particular region of the casting.

It is a primary object of the present invention to provide method and apparatus for producing pistons or other articles wherein the formation of voids in the interior of the casting due to solidification shrinkage is eliminated.

It is an ancillary object of the invention to provide methods and apparatus in accordance with the foregoing objects wherein an exceedingly fine grained casting of uniform density is produced.

Another object of the present invention is to provide a

method of molding pistons under high-pressure conditions.

A still further object of the present invention is to provide a method of making molded aluminum pistons.

A still further object of the present invention is to provide a method of manufacturing internal combustion engine type pistons by filling the die cavity of molding apparatus with molten metal followed by the insertion of a core into the metal in the cavity to form the interior of the piston and thereafter controlling the flow of metal under pressure.

It is yet another object of the present invention to provide high pressure molding apparatus for the manufacture of components of irregular contour.

A still further object of the present invention is to provide apparatus requiring a minimum number of parts for high pressure molding of molten metal.

Yet another object of the present invention is to provide pistons molded under high pressure conditions requiring a minimum of finishing and of fine grain and high structural strength.

A still further object of the present invention is to provide apparatus for high pressure molding of pistons which is simple and compact in construction and efficient and high speed in operation.

The foregoing and other objects are achieved in a process wherein molten metal is charged into a die cavity which is then subsequently sealed. After the die cavity is sealed and while the metal within the cavity is cooling, one or more plungers are forced into the cavity and pressure is applied to the plungers until the metal is completely solidified. Two important advantages are achieved by the foregoing operation. First, the insertion of the plunger into the die cavity reduces the volume of the cavity by an amount which exceeds the reduction in volume of the molten metal due to the solidification shrinkage. Stated another way, the insertion of the plungers forces the metal of the casting into the void which would otherwise be formed by solidification shrinkage. Second, by choosing the potential reduction of volume of the die cavity by the introduction of the plungers to their full extent to achieve a reduction in volume greater than the total volume of solidification shrinkage, the plungers substantially increase the internal pressure on the casting while it is still in a plastic state, thereby achieving a finer grain or more "firmly packed" casting.

Preferably, the plungers are forced into the cavity by means of hydraulic motors to which a constant pressure is applied, whereby the plungers continue to drive into the molten or plastic metal until the pressure exerted on the plunger by the hydraulic motor is counterbalanced by the back pressure developed in the plastic metal.

In the case of a piston casting which is to be subsequently machined to provide a diametrically extending wrist pin bore, the plungers are conveniently applied to the casting in radially inwardly directed manner within the regions from which the wrist pin bore is to be subsequently machined. The plungers are so dimensioned and aligned with the casting configuration that the recess or indentation formed in the casting by the plungers during the casting operation is completely within that region of the casting which will subsequently be removed when the wrist pin opening is subsequently machined.

Other objects and features of the invention will become apparent by reference to the following specification and to the drawings.

FIGURE 1 is a front elevational view of a molding apparatus embodying the present invention;

FIGURE 2 is a detailed cross-sectional view of the apparatus shown in FIGURE 1, with certain parts broken away or omitted for clarity and showing the parts positioned at one step of the process;

FIGURE 3 is a detailed cross-sectional view of the mold of FIGURE 2, showing certain parts in the next subsequent step of the process to that of FIGURE 2;

FIGURE 4 is a detailed cross-sectional view similar to FIGURE 2 showing the parts as positioned near the conclusion of the molding operation;

FIGURE 5 is a detailed cross-sectional view of a completed piston formed from a blank molded by apparatus of FIGURES 1 through 4;

FIGURE 6 is a detailed cross-sectional view, similar to FIGURE 5, showing approximately one-half of the piston blank after it has been removed from the mold and prior to the boring of the wrist pin openings shown in FIGURE 5.

As shown in FIGURE 1, one form of apparatus embodying the invention includes a base assembly designated generally 10 of any suitable construction, upon which is mounted a table 12.

A cavity defining die member 14 of suitable construction is mounted upon table 12 by any suitable means such as restraining members 16. Die member 14, as best seen in FIGURE 2, defines a cavity 18 which has conformed to the top and outer side surface configuration of the piston casting to be molded. The internal surfaces of the piston casting are determined by a core 20 which is fixedly secured to a platen 22 mounted for vertical sliding movement on a plurality of posts 24 fixedly mounted upon table 12. At the upper end of post 24, a plate 26 is fixedly mounted to support the cylinder of a reversible pneumatic or hydraulic motor 28 whose piston rod 30 is fixedly secured to platen 22 to vertically reciprocate the platen and core 20 upon actuation of motor 28.

As best seen in FIGURE 2, an upwardly projecting sealing lip 32 is formed on the top surface of die member 14 and a collar 34 slidably mounted upon platen 22 is formed with a mating recess 36 which is adapted to receive sealing lip 32 to define a pressure tight seal between the collar and die member when the die is closed as shown in FIGURES 3 and 4. Collar 34 is slidably mounted on a projection 40 of platen 22 and is coupled to platen by a plurality of bolts 42 received in the platen for vertical sliding movement. Each bolt 42 has associated therewith a compression spring 44 which normally biases collar 34 to a lower limit of movement relative to platen 22 shown in FIGURE 2. When platen 22 is driven to its lower position, shown in FIGURES 3 and 4, springs 44 are compressed to resiliently seat collar 34 in sealing engagement with die member while permitting core 20 to be moved to its final position within cavity 18.

Referring now to FIGURE 5, there is shown a piston designated P which is formed from a piston casting B (FIG. 6) molded in the apparatus described above. The completed piston P shown in FIGURE 5 is provided with a pair of diametrically opposed radially extending wrist pin receiving openings W which are employed to connect the piston to the connecting rod. Wrist pin openings W are required to be formed to a quite close tolerance and hence are machined after the formation of the casting B in the molding apparatus.

Referring now to FIGURE 6, there is shown a partial cross-sectional view of a piston casting B as it comes from the mold, prior to the machining of the wrist pin openings, the wrist pin bore being indicated in broken line at W in FIGURE 6. As is apparent from FIGURE 6, the piston casting is formed with a recess R which extends radially into the wall of the piston casting, recess R being circular in cross-section and extending coaxially of the centerline of the wrist pin opening which is to be subsequently formed.

Recesses R are formed during the molding operation by a pair of cylindrical plungers 50 which are slidably received within bores 52 to extend radially of die cavity 18. Bores 52 are located relative to the die cavity to achieve the desired alignment with that portion of the casting B in which the wrist pin openings W are to be formed. Each of plungers 50 is carried upon the piston rod of an expansible chamber motor designated generally 54, each motor 54 being mounted upon table 12 by a suitable bracket 56. Motors 54 are identical in construction and are connected to a suitable source of hydraulic power so that both of plungers 50 are simultaneously located either in the retracted positions shown in FIGURE 2 or the extended position shown in FIGURE 4.

The formation of recesses R in the piston blank B during the molding operation is only incidental to the primary function of plungers 50.

The advancing movement of plungers 50 into the molten metal within cavity 18 reduces the volume of the sealed cavity available to be occupied by metal. Plungers 50 are advanced into the cavity while the molten metal in the cavity is cooling from its liquid to its solid state and, during the transition of the metal from liquid to solid state, solidification shrinkage occurs, thereby reducing the total volume of metal within cavity 18. The reduction in volume of the cavity, however, by the movement of plungers 50 into the cavity fully compensates for the reduction in volume of the metal as it solidifies, because the constant pressure applied to the plungers by motors 54 causes the plungers to move further into the cavity upon a reduction in back pressure from the metal occasioned by shrinkage of the metal.

The sequence of steps of the molding operation is shown successively in FIGURES 2, 3 and 4. FIGURE 2 shows the various parts and the positions assumed by them immediately subsequent to the charging of the die with a sufficient volume of molten metal. At this time, platen 22 is in its elevated position and core 20 is thus supported clear of die member 14. Both of plungers 50 are in their retracted position in which the ends of the plungers are withdrawn into their respective bores 52. It is not absolutely essential that the plungers be withdrawn to the extent disclosed in FIGURE 2, the retracted position of the plungers may find the plungers at any convenient position wherein the ends of the plungers do not project outwardly from bores 52 into cavity 18.

Substantially immediately after the die cavity has been charged with molten metal as shown in FIGURE 2, motor 28 is actuated to drive platen 22 to its lowermost position wherein collar 34 forms a seal with the upper surface and lip 32 of die member 14, thereby sealing die cavity 18. Recess 36 extends inwardly beyond the inner side of lip 32 and closely adjacent core 20, and angular projection 60 on the lower surface of collar 34 is located almost, but not quite, in contact with the upper side of die member 14. Recess 36 thus provides an annular overflow chamber to compensate for the volume of molten metal with which die member 14 is charged exceeds the capacity of the closed die cavity.

The space between the lower edge of annular projection 60 and the upper surface of die member 14 is relatively small, and this relatively thin section of molten metal cools quite rapidly.

After the die is closed, pressure is supplied to motors 54 to extend their piston rods, thereby driving plungers 50 radially into cavity 18.

As explained above, the molten metal when in its liquid state occupies a greater volume than it does when in its solid state. Thus, when plungers 50 initially move into the cavity, substantially all of the molten metal within the cavity is still in its liquid state and since the cavity is filled upon the closing of the die, plungers 50 cannot move very far into the cavity until the back pressure exerted by the molten metal counterbalances the radially inwardly directed pressure exerted on the plungers by motors 54. However, as the metal begins to solidify, the total volume occupied by the metal within the cavity, both in liquid and in solid state, decreases, and as the volume of metal decreases, the back pressure on plungers 50 correspondingly reduces. The constant pressure exerted upon the plungers 50 by motors 54 urges the plungers deeper into the cavity, thereby continually reducing the volume of the cavity in exact correspondence to the amount of solidification shrinkage occurring in the metal as it passes from the liquid into the solid state. Thus, movement of plungers **50** into the cavity **18** produces a precise compensation for the solidification shrinkage or metal volume loss during transition from the liquid to solid state.

Two important results are achieved by the foregoing action. First, the inwardly moving plungers prevent the formation of voids in the interior of the casting by positively displacing the metal while still in a liquid or plastic solid state to thereby require the metal to fill the region in which the void would otherwise have occurred. Second, the plungers **50** apply a positive pressure to the metal while it is cooling, and this pressure is constant throughout the cooling process to thereby result in a tight "packing" of the molecules of the metal. This action results in a fine grained casting of substantially uniform density throughout.

Pressure is maintained in motors **54** until the charge within die **14** solidifies. Motors **54** are then reversed to retract plungers **50** clear of cavity **18** and the mold is opened by elevating platen **22**. The casting is removed from the mold in any suitable manner.

From the foregoing, it will be noted that the displacing and pressurizing of the molten metal during cooling is accomplished independently of any mold or die surface which determines the final shape of the finished article. Uniformity of physical characteristics of the completed casting are achieved because the manner in which the metal is displaced and pressure is applied is self-compensating. Self-compensation is in turn possible because the plungers are forced against the molten metal in a region which will be subsequently removed during finishing of the part, and thus the configuration and depth of the recess R formed in the blank B is immaterial, the sole requirement as pointed out above being that the recess be entirely contained within the region which will subsequently be removed by the machining of the wrist pin openings.

While one particular form of the invention has been disclosed and described in detail, it will be apparent to those skilled in the art, that the disclosed embodiment may be modified. 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. Apparatus for high-pressure permanent molding of articles from molten metal comprising: die means defining a die cavity having a relatively large portion defining a relatively thick section of the article to be formed, means defining a pair of compensating passages extending into the sides of said die means from said large portion of said cavity for receiving metal displaced from said die cavity by a core inserted in the die cavity for applying article-forming pressure to molten metal therein, and means including a movable member in each passage adapted to force said displaced molten metal from said passage into said die cavity to compensate for metal volume loss due to cooling-caused shrinkage in the die cavity.

2. Apparatus for high-pressure permanent molding of an article having at least one relatively thick section from molten metal comprising: a die cavity defined by a die means and having an enlarged portion defining the thick section of said article, compensating passage means formed in the side of said die means at said enlarged portion for receiving metal from said die cavity when said cavity is filled with molten metal, and means including a movable member in said passage means for forcing said displaced molten metal from the passage means into the die cavity to compensate for metal volume loss due to cooling-caused shrinkage.

3. Apparatus adapted for high-pressure permanent molding of an article having at least one relatively thick section, said apparatus comprising: die means defining a pressurizable die cavity conformed to the shape of said article for receiving a core adapted to apply article-forming pressure on molten metal in said die cavity, at least one passage formed in a side wall of the die means and directly comunicating with the die cavity at that portion of said cavity defining the relatively thick section of the article for receiving molten metal from said die cavity displaced by said core, and a movable member disposed in said passage for forcing said displaced molten metal into the die cavity to compensate for metal volume loss due to cooling-caused shrinkage in the die cavity.

4. Apparatus adapted for high-pressure permanent molding comprising: die means defining a pressurizable die cavity having an enlarged portion defining a thickened section of an article to be formed, at least one passage formed in a side wall of the die means at and in direct communication with the enlarged portion of said die cavity whereby said passage is filled with molten metal when said die cavity is filled with molten metal and pressurized, and a movable member disposed in the passage for forcing said displaced molten metal from the passage into the die cavity to compensate for metal volume loss due to cooling-caused shrinkage.

5. Apparatus for high-pressure permanent molding of an article having a plurality of relatively enlarged sections comprising: die means defining a pressurizable die cavity, a plurality of passages formed in the side of said die means and in direct communication with the respective portions of the die cavity at a point in said side defining the relatively enlarged sections of the article for receiving molten metal displaced by a core inserted in the pressurizable die cavity for applying article-forming pressure to molten metal in the die cavity, and a movable member disposed in each passage for forcing displaced molten metal from the passage into the die cavity to compensate for metal volume loss due to cooling-caused shrinkage.

6. Apparatus for high-pressure molding comprising: die means defining a pressurizable die cavity, a pair of diametrically opposed passages formed in a side of the die means at and in direct communication with diametrically opposed enlarged portions of the die cavity for receiving molten metal displaced from the die cavity by a core inserted therein for applying article-forming pressure to molten metal in the cavity, and a movable member disposed in each passage for forcing said displaced molten metal into the die cavity to thereby compensate for metal volume loss due to cooling-caused shrinkage.

7. The method of molding a piston casting wherein radially extending wrist pin openings are to be formed at predetermined locations in said casting subsequent to the molding thereof comprising the steps of charging a sealable piston die cavity with a charge of molten metal sufficient to fill the cavity when sealed, sealing said cavity with said charge therein, and forcing pressure applying plungers radially into the molten metal in said cavity at each location where a wrist pin opening is to be formed in the piston, and exerting a predetermined pressure on said plungers until the molten metal in said cavity has solidified.

8. The method of making a casting having relatively thick sections and relatively thin sections from a metal having relatively high solidification shrinkage characteristics comprising the steps of filling a die cavity with a charge of molten metal, said die cavity having a major portion conforming in shape to the shape of the casting and a minor portion constituting a reservoir extraneous to the casting in direct communication with said major portion at a location in the wall of the die cavity wherein said major portion defines a relatively thick section of said casting, sealing the die cavity, and applying pressure to molten metal in the minor portion of the cavity to feed molten metal under pressure from the minor portion of the cavity into the major portion of said cavity.

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126,544	1/1948	Australia.

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