(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 127 366**
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(12) # EUROPEAN PATENT APPLICATION

(21) Application number: 84303241.8

(22) Date of filing: 14.05.84

(51) Int. Cl.³: B 22 D 15/02
B 22 D 27/15, B 22 D 27/11

(30) Priority: 31.05.83 US 499611

(43) Date of publication of application: 05.12.84 Bulletin 84/49

(84) Designated Contracting States: DE FR GB IT

(71) Applicant: GIBBS DIE CASTING ALUMINUM CORPORATION
Highway 60
South Henderson Kentucky 42420(US)

(72) Inventor: Lindsey, John L.
202 Shenandoah Place
Henderson Kentucky 42420(US)

(74) Representative: Blatchford, William Charles et al,
WITHERS & ROGERS 4 Dyers Buildings Holborn
London, EC1N 2JT(GB)

(54) **Method of die casting a piston.**

(57) A method (Figure 4) of die casting an automobile engine piston includes the steps of moving one (24) of two halves (20, 24) to form a mould cavity (28) having the shape of a piston, introducing molten metal (31) into the cavity (28) through gates, cooling the metal for an interval of time sufficient for the metal to solidify in the gates, and thrusting a plunger (14) into the cavity (28) to displace the molten metal to form an opening in the piston and to compress the displaced metal to intensify mechanical properties of the metal surrounding the opening. The plunger (14) is moved from a first position outside the cavity (28) until pressure within the displaced metal stops the plunger in a second position in the cavity. The plunger is retained in the cavity for a predetermined time and is then retracted to the first position.

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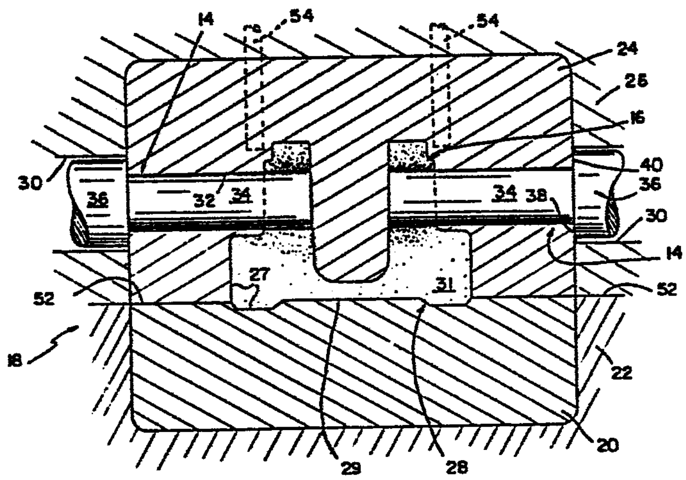

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FIG. 4

Method of Die Casting A Piston

This invention relates to a method of die casting an internal combustion engine piston of the type used in automobiles, and particularly to a method involving the formation of wrist pin openings in die cast pistons.

A trunk-type piston typically forms the movable end of a cylinder in an internal combustion engine. Rapid expansion of vapors and gases within the cylinder following combustion causes displacement of the piston. Conventional trunk-type pistons include a closed "face" end and an opposing skirt to align the piston properly in the cylinder. A piston rod communicates with both the piston skirt and a conventional connecting rod. The piston rod is one link in a conventional mechanical engine linkage. The linkage transforms the rectilinear motion of the piston within the cylinder into the rotational motion required to drive a shaft.

One end of a conventional piston rod includes a pair of opposing inwardly facing wrist pins. Typically, the piston skirt includes a pair of internal bosses having opposing outwardly facing openings to receive and support the wrist pins of the piston rod. Not unexpectedly, the piston material surrounding the wrist pin opening is subjected to immense compressive, tensile, and shear stresses due to the alternating load transmitted by the wrist pins during engine operation, particularly in automobiles. Accordingly, the fatigue strength of the material adjacent the wrist pin opening should be maximized to guard against catostrophic stress-related failure after an unacceptably low number of operating cycles. These engineering requirements cannot be achieved at present using die casting techniques due to process limitations that have hindered development of the piston die casting art.

In conventional die casting techniques, porosity is present in the finished product. Two types of porosity are present: (1) gas porosity caused by trapped gas or air; and (2) porosity formed by shrinkage of the metal. Either one of these types of porosity may cause a piston to expand, blister, and explode at operating temperatures encountered in automobile internal combustion engines. For these reasons, die casting techniques have not heretofore been used to produce pistons for automobile internal combustion engines.

Automobile pistons are presently cast without wrist pin openings using a permanent mold casting process since the die casting industry has been unable to increase the fatigue strength of the material surrounding the opening to tolerable levels using a die casting process. An aluminum alloy is the most commonly selected piston material. Presently, secondary drilling and reaming operations must be performed on every cast or machined piston to provide the wrist pin openings.

Even in the permanent mold casting process, steel struts have been used as mold inserts in an attempt to increase the fatigue strength of the aluminum. The steel struts have been used in the permanent mold casting process primarily to strengthen the area around the wrist pin openings. It is also known to use steel struts in the area of the ring groove cut in the closed "face" end of the piston to increase strength in the permanent mold casting process.

Methods of altering mechanical properties of die cast items are known. An apparatus for producing dense articles from molten materials is disclosed in U.S. Patent No. 3,268,960 (Morton). The apparatus disclosed in Morton comprises a vacuum die casting machine in combination with means for forging selected portions of molten material within the mold cavity to produce articles of high-density character. The forging is accomplished by initial and continuing pressure on the molten material until it has solidified and cooled. However, Morton does not teach a method of ramming a plunger into the molten material in the mold cavity in order to form an opening and intensify certain mechancial properties of the cast item surrounding the opening. Accordingly, significant secondary machining operations would still be required to fabricate wrist pin openings in a die cast trunk-type piston.

The present invention provides a method of die casting pistons for automobile internal combustion engines in which intensifying plungers are used to form wrist pin openings. The plungers can be hydraulically thrust into the semi-molten metal already injected into the mold cavity to simultaneously displace the metal to form the wrist pin openings and compress the displaced metal within the mold cavity to intensify the critical mechancial properties of the metal surrounding the wrist pin openings. Not only does the present invention provide a unitary method of forming wrist pin openings in die cast pistons, but it concurrently maximizes the fatigue strength of the metal surrounding the wrist pin opening to forestall ruinous piston failure due to stress fracture during engine operation. The need for costly, labor-intensive secondary machining is minimized and intensifying procedures are not required to form wrist pin openings in pistons produced using the method of the present invention.

In accordance with the present invention, a method of die casting a piston for an internal combustion engine includes the steps of forming a mold cavity for casting the piston, introducing a molten metal into the mold cavity through gates in order to substantially fill the cavity, cooling the introduced molten metal until it solidifies in the gates to close the cavity, and thrusting a plunger into the mold cavity to displace and compress the molten metal within the cavity. The plunger forms an opening in the piston and compresses the displaced metal to intensify mechanical properties of the metal surrounding the opening.

The introducing step can include the steps of transferring a predetermined quantity of molten metal from a reservoir maintained at a predetermined pressure to a channel in communication with the reservoir, by producing a pressure in the mold cavity below the predetermined pressure. The lower pressure in the mold cavity will induce molten metal to leave the reservoir and enter the channel. A plunger pushes the metal from the channel into the mold cavity through relatively small gates. Before thrusting the plungers into the mold cavity, the molten metal is allowed to solidify or "freeze" in the gates to close the cavity and prevent metal from being forced back into the channel. The time required for the metal to "freeze" in the gates will depend upon the gate size, the freeze curve of the metal alloy, and the thickness of the casting.

The thrusting step can include the steps of moving the plunger in a cylinder communicating with the mold cavity, actuating a fluid motor connected to the plunger so that the plunger is moved from a first position within the cylinder to a second position within the cavity, retaining the plunger within the cavity for at least a predetermined interval of time, and thereafter actuating the fluid motor so that the plunger is retracted to its first position within the cylinder. The thrusting step can also include the step of ramming two opposing plungers into the molten metal to displace the metal to form a pair of wrist pin openings in the cast piston. In the thrusting step, the plungers are moved into the cavity until back pressure from the compressed molten metal stops the motion of the plunger. The plunger should be stopped by the back pressure before it reaches a predetermined limit to ensure that adequate pressure is created on the molten metal and maintained during the solidification of the metal.

This invention may best be understood by a reference to the following descripton of a preferred embodiment and the accompanying drawings. In the drawings:

Fig. 1 is an isometric view of a pair of intensifying plungers received within the wrist pin openings of a die cast piston of the present invention;

Fig. 2 is a top plan view, partly broken away and cross-sectioned, of the die casting apparatus showing the relationship of the intensifying plunger conduits to the mold cavity of the present invention;

Fig. 3 is a sectional detail view, partly cross-sectioned, of an embodiment of the present invention showing the intensifying plungers prior to entry into the mold cavity taken generally along line 3-3 of Fig. 2;

Fig. 4 is a sectional detail view, partly cross-sectional, of an embodiment of the present invention showing the intensifying plunger thrust into the molten metal within the mold cavity to form the wrist pin openings and compress the metal surrounding the wrist pin openings taken generally along line 3-3 of Fig. 2.

Throughout the following detailed description of the present invention and the claims, reference is made to the formation of a "piston." In the description and the claims, it is intended that the word "piston" mean a large internal combustion engine piston of the type used in vehicles such as automobiles.

As shown in Fig. 1, the casting method of the present invention produces a die cast piston 10 having internal bores or wrist pin openings 12 formed and intensified by a pair of thrustable intensifying plungers 14. As is customary, the wrist pin openings 12 are formed in opposing faces of the piston skirt 16 to receive and support the inwardly projecting wrist pins of a conventional piston rod (not shown). Preferably, the intensifying plungers 14 cooperate with a metal die 18 in a cold chamber vertical die casting machine to form and intensify the wrist pin openings as shown in Figs. 2, 3, and 4.

The metal die 18 includes a stationary die 20 seated in a cover holding block 22 and an opposing movable die 24 seated in an ejector holding block 26. Each of the dies 20, 24 includes a cut-away portion 27 suitably configured and located so that they cooperate to form a mold cavity 28 having the shape of a piston when the dies 20, 24 are mated. Preferably, the piston skirt 16 is molded in the cut-away portion 27 of the movable die 24, the closed "face" end 29 being molded in the cut-away portion 27 of the stationary die 20. Therefore, the movable die 24 and the adjacent ejector holding block 26 include plunger-receiving passageways

30, 32 so that intensifying plungers 14 can be thrust into the mold cavity 28 after the dies 20, 24 are mated and molten metal 31 has been allowed to substantially fill the mold cavity 28.

Each plunger 14 is normally housed within a first cylindrical passageway or portion 30 formed in the ejector holding block 26 and is movable therein. Each first cylindrical passageway 30 communicates with the mold cavity 28 via a coaxial second cylindrical passageway or portion 32 of a smaller cross-sectional area formed in the movable die 24, as shown in Fig. 3.

Each plunger 14 includes a flat-faced tip portion 34 and a base portion 36. The tip portion 34 is movable to a position within the movable die 24 to form a wall portion of the mold cavity 28 during introduction of molten metal, as shown in Fig. 3. The tip portions 34 are held approximately tangent to the outside diameter of the mold cavity 28 so that very little molten metal 31 will enter the passageway 32. Thereafter, the tip portion 34 is thrust into the mold cavity 28, thereby piercing the molten metal 31 contained therein to form and intensify the wrist pin openings 12 as shown in Fig. 4.

Accordingly, the cross-sectional area of the tip portion 34 must be of sufficient size to pass through the second cylindrical passageway 32 to enter the mold cavity 28. Preferably, the diameter of the plunger tip portion 34 of the plunger 14 is about 0.004 inch to 0.005 inch smaller than the diameter of the passageways 32 in the dies through which they pass. The base portion 36 is provided with an annular flange 38 having a cross-sectional area of sufficient size to engage the outer surface 40 of the movable die 24 to thereby limit travel of the tip portion 34 into the mold cavity 28 to a predetermined distance.

Each plunger 14 is propelled by a fluid motor 42. The fixed portion of the fluid motor 42 is securely mounted to the ejector holding block 26 as shown in Fig. 2 at 44 and the movable portion is attached to the plunger base portion 36 to selectably move the plunger 14 within passageways 30, 32 to thrust the tip portion 34 into the mold cavity 28. In one embodiment, the fluid motor 42 is a conventional hydraulic piston and cylinder mechanism. As will be explained later, the hydraulic pressure generated by the fluid motor 42 should be adequate to generate a force that will create effective pressures in the molten metal 31 of about 15,000 psi to 30,000 psi.

A vacuum pump (not shown) is used to induce a partial vacuum in the mold cavity 28 and in the molten metal feed conduits 46 that connect the mold cavity 28 to a molten metal reservoir (not shown). The vacuum pump communicates with the mold cavity 28 and molten metal feed conduit 46 via a vacuum chill block and pull gate combination as shown in dotted lines in Fig. 2 at 48. Vacuum is pulled through the chill block and gate combination 48 to pull molten metal from the reservoir into the feed conduit 46. In one embodiment, 28 inches of mercury vacuum is pulled in the cavity 28.

The method of the present invention can best be understood by reference to Figs. 2, 3, and 4. The cover and ejector holding blocks 22, 26 are preferably mounted on a vertical die casting machine, and the movable and stationary dies 20, 24 are mounted in the blocks 22, 26, respectively. As soon as the two dies 20, 24 are mated and sealed under lock-up pressures, a partial vacuum is induced in the mold cavity 28 and feed conduits 46. The vacuum is transmitted through the feed conduits 46 to the molten metal reservoir through a conventional shot sleeve and transfer tube (not shown).

The molten metal 31 is drawn into the shot sleeve through the transfer tube by the vacuum. Use of the vacuum prevents air bubbles from forming in the molten metal.

As soon as enough molten metal 31 is in the shot sleeve, a shot cylinder/plunger apparatus (not shown) pushes the molten metal into the mold cavity 28 through a plurality of gates 50, resulting in a pressure of about 2,500 psi to 5,500 psi on the molten metal 31. Excess metal is captured in overflows 49. The gates 50 are formed in the lowermost portion of the movable die 24 just above the parting line 52, shown in Figs. 3 and 4. Prior to filling the cavity 28 with molten metal, fluid motors 42 are activated to move the plungers 14 in the movable die passageways 30, 32 so that the flat face of the tip portion 34 forms a portion of the wall of the mold cavity, thereby preventing flow of molten metal 31 into the movable die passageway 32. The pressure of 2,500 psi to 5,500 psi is exerted on the molten metal 31 in the mold cavity 28 until the metal 31 in the gates 50 solidifies or freezes. In a preferred embodiment, the cavity 28 is filled with molten metal 31 and the freezing in the gates 50 begins approximately one to two seconds after the vacuum is induced in the mold cavity 28. The solidification of the metal in gates 50 closes the mold cavity 28 to prevent backflow of metal into the shot sleeve when plungers 14 are thrust into the cavity 28.

The fluid motors 42 are once again activated to thrust the intensifying plungers 14 under high pressure directly into the molten mass of the casting as soon as the metal in the gates 50 has frozen. Preferably, the plunger tip portion 34 will pierce the molten metal 31 about one-half second after the mold cavity 28 is full of metal. However, the plunger tip portion 34 could be thrust into the cavity 28 up to eight seconds after the cavity 28 is full. The exact time interval depends upon port 48 size, the freeze curve of the alloy being cast, and the thickness of the section of casting into which the plunger 14 is being thrust.

The plungers 14 are thrust as far as possible into the semi-molten metal 31 in the cavity 28. The plungers 14 help to create effective pressures of about 15,000 psi to 30,000 psi in the molten metal 31 within the mold cavity 28. Normal pressures achieved in conventional die casting range from about 4,000 psi to 10,000 psi. The plunger 14 pierces and compresses the semi-molten metal 31 until the pressure within the mass of metal 31 becomes great enough so that back pressure on the plunger tip 34 stops forward motion of the plunger 14 into the cavity 28. It is preferred that forward motion of the plunger 14 be stopped by back pressure on the tip 34 before the annular flange 38 of the plunger base portion 36 bottoms out on the outer surface 40 of the movable die 24 to ensure that adequate pressure is created in the molten metal mass 31 and held throughout the freezing process. Accordingly, the depth of penetration of the plunger tip 34 will vary but will be equal to or less than the predetermined distance of travel of the plungers 14.

The plungers 14 are subsequently retracted from the mold cavity 28 to allow the molded piston to be ejected from the separated dies 20, 24 by a plurality of ejector pins 54. Preferably, the plungers 14 remain in the mold cavity 28 at least until the metal has cooled and frozen and the plungers 14 are therefore no longer effective. In the present invention, the plungers 14 are not withdrawn until just before the die 18 is opened. Following ejection, the fully formed piston 10 having wrist pin openings 12 can be machined to conform to operating specifications.

Although the invention has been described in detail with reference to certain preferred embodiments, variations and modifications exist within the scope and spirit of the invention as described and defined in the following claims.

CLAIMS:

1. A method of die casting a piston comprising the steps of:

(a) moving a movable die having a first cut-away portion to mate with a stationary die having a second cut-away portion, the cut-away portions of the mated dies cooperating to form a mold cavity having the shape of a piston,

(b) introducing a molten metal through gates into the mold cavity to substantially fill the cavity,

(c) cooling the introduced molten metal to solidify the metal in the gates, and

(d) subsequent to solidification of the metal in the gates, thrusting a plunger into the molten metal admitted into the mold cavity to displace the molten metal to form an opening in the piston and to compress the displaced metal to intensify mechanical properties of the metal surrounding the opening.

2. The method of claim 1 wherein the thrusting step further comprises the steps of:

(a) moving the plunger in a cylinder communicating with the mold cavity,

(b) actuating a fluid motor connected to the plunger to extend the plunger into the mold cavity from a first position within the cylinder,

(c) moving the plunger into the mold cavity until pressure within the displaced metal stops the plunger in a second position,

(d) retaining the plunger within the cavity for a predetermined interval of time, and

(e) thereafter actuating the fluid motor to retract the plunger to the first position.

3. The method of claim 2 wherein the actuating step further comprises moving the plunger from the first position in a first cylinder portion to the second position in the mold cavity through a coaxial second cylinder portion, the second cylinder portion having a smaller cross-sectional area than the first cylinder portion to engage a flange of the plunger to limit the movement of the plunger into the mold cavity to a predetermined distance.

4. A method of forming wrist pin openings in die cast pistons comprising the steps of:

(a) moving a movable die having a first cut-away portion to mate with a stationary die having a second cut-away portion, the cut-away portions of the mated dies cooperating to form a cavity having the shape of a piston,

(b) introducing a molten metal into the cavity through a plurality of gates so that the molten metal substantially fills the cavity,

(c) cooling the introduced molten metal for an interval of time sufficient for the metal to solidify in the gates, and

(d) ramming two opposing plungers into the semi-molten metal to displace the metal to form a pair of wrist pin openings and to compress the displaced metal to intensify the mechanical properties of the metal surrounding the openings.

5. A method of forming wrist pin openings in a piston comprising the steps of:

(a) forming a mold cavity for casting the piston,

(b) transferring at least a predetermined quantity of molten metal from a reservoir maintained at a predetermined pressure to a channel in communication with the reservoir,

(c) introducing a predetermined quantity of molten metal from the channel through gates into the mold cavity to substantially fill the mold cavity,

(d) cooling the introduced molten metal for an interval of time sufficient for the metal to solidify in the gates,

(e) driving two opposing plungers into the mold cavity to displace the molten metal contained therein,

(f) moving the plungers into the mold cavity until pressure within the displaced metal stops the plungers,

(g) retaining the displaced molten metal within the mold cavity, and

(h) retracting the plungers from the mold cavity to a position external to the mold cavity to produce two wrist pin openings in the piston.

6. A method of forming wrist pin openings in a die cast piston comprising the steps of

(a) moving a movable die having a first cut-away portion to mate with a stationary die having a second cut-away portion, the cut-away portions of the mated dies cooperating to form a mold cavity having the shape of a piston,

(b) inducing a partial vacuum in the cavity to cause the molten metal to flow from a molten metal source to a channel,

(c) forcing a quantity of metal through the channel and gates under pressure into the cavity,

(d) cooling the molten metal to solidify the metal in the gates, and

(e) thrusting a plunger into the molten metal admitted into the mold cavity to displace the molten metal to form a wrist pin opening and to compress the displaced metal to intensify mechanical properties of the metal surrounding the opening.

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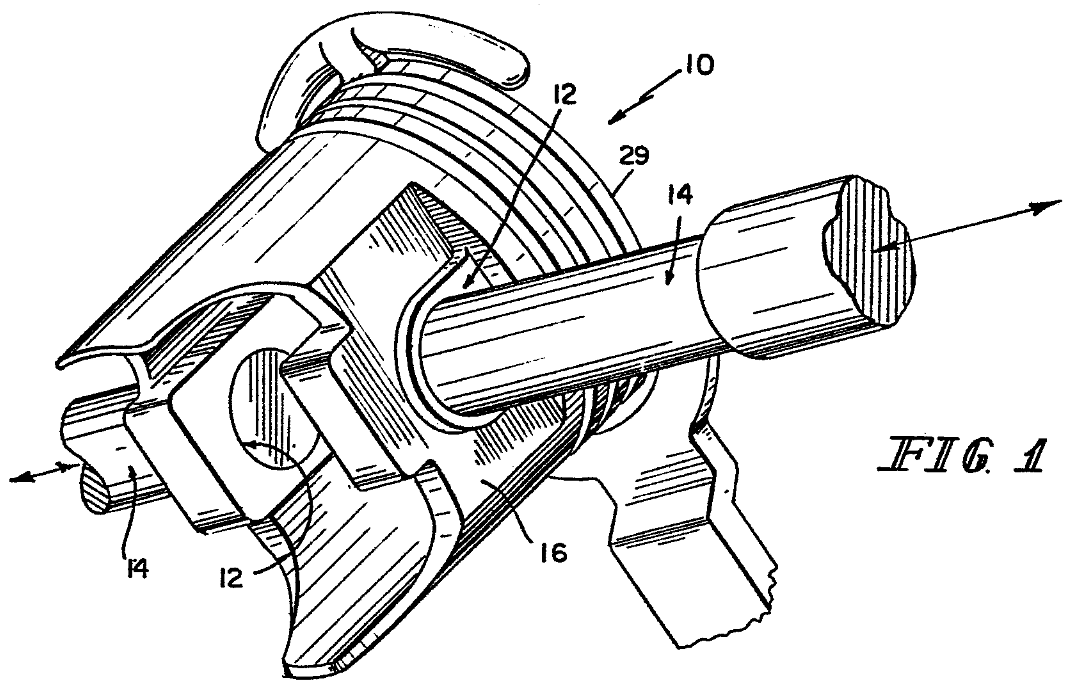
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FIG. 1

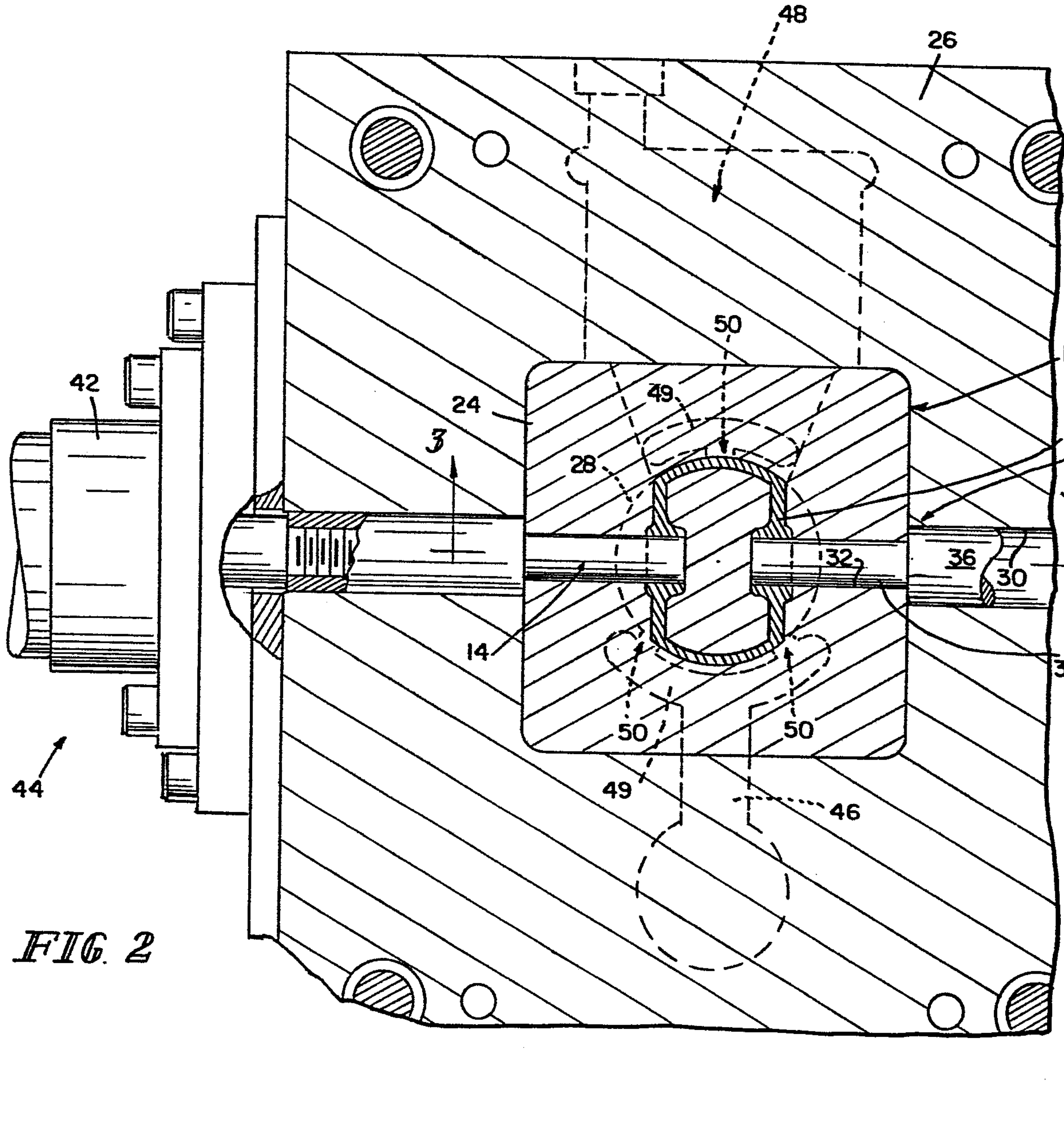
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FIG. 2

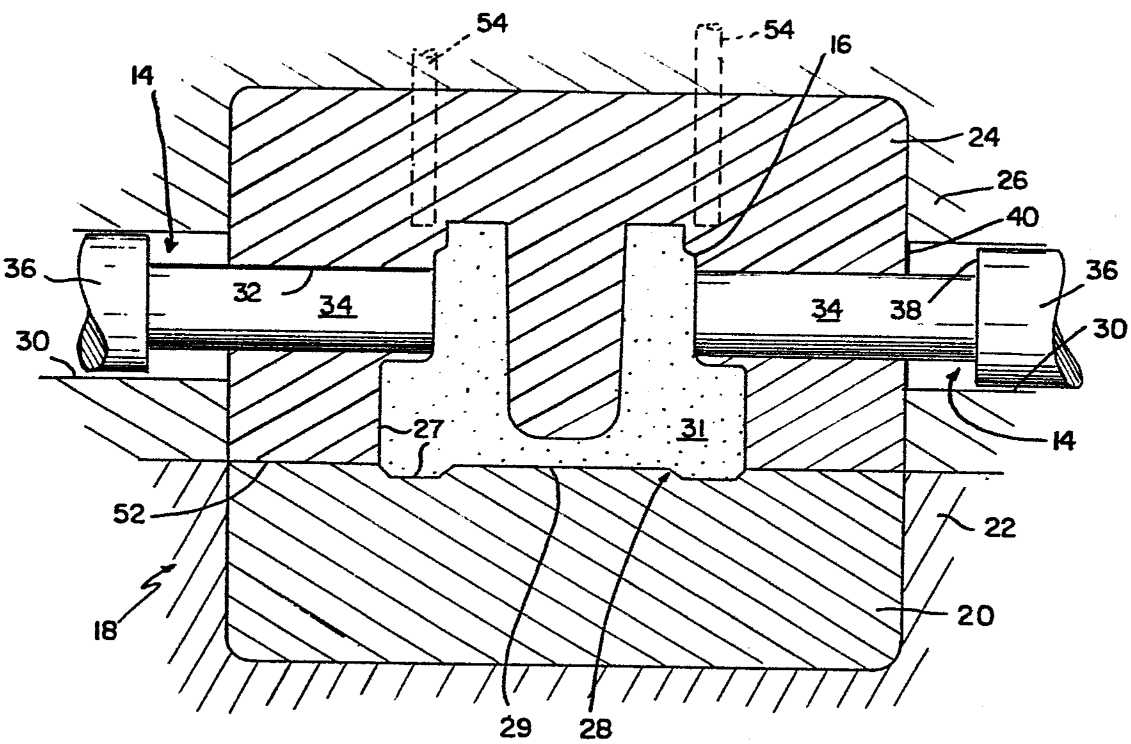
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FIG. 3

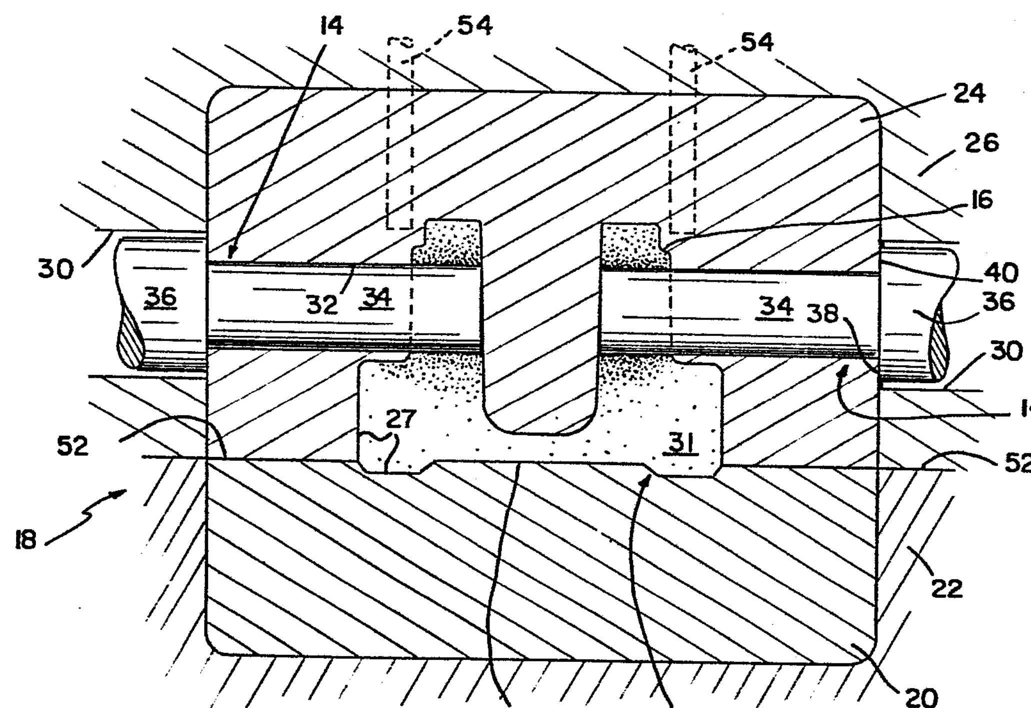
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FIG. 4

European Patent Office

EUROPEAN SEARCH REPORT

0127366

Application number

EP 84 30 3241

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
X	US-A-3 068 539 (WILCOXON) * Column 5, line 75 - column 6, line 2 * ---	1,2,4, 5	B 22 D 15/02 B 22 D 27/15 B 22 D 27/11
D,A	US-A-3 268 960 (MORTON) * Column 2, line 8 - column 3, line 4 * ---	6	
A	US-A-2 057 074 (WESSELER) * Page 3, right-hand column, lines 66-68 * -----	3	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
			B 22 D 15/02 B 22 D 15/00 B 22 D 27/15 B 22 D 27/11

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	28-08-1984	SCHIMBERG J.F.M.

CATEGORY OF CITED DOCUMENTS

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