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Mitamura et al.

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[54] **PRESSURE INTENSIFYING APPARATUS FOR A DIE CASTING MACHINE**

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[51] **Int. Cl.**..........................**B22d 17/32,** B22c 19/04

[58] **Field of Search**.......................164/303, 312, 313, 164/314, 315, 318, 337, 154, 155

[56] **References Cited**

UNITED STATES PATENTS

2,228,973	1/1941	Polak	164/315
2,243,835	6/1941	Brunner	164/314 X
2,259,781	10/1941	Shaw	164/315 X
2,433,132	12/1947	Lester	164/314 X
2,484,907	10/0949	Purcell	164/315 X
2,634,468	4/1953	Holder	164/315
3,040,399	6/1962	Raffaelli	164/314 X
3,491,827	1/1970	Mace	164/315 X
3,536,128	10/1970	Bachelier	164/314
3,693,702	9/1972	Piekenbrink	164/314

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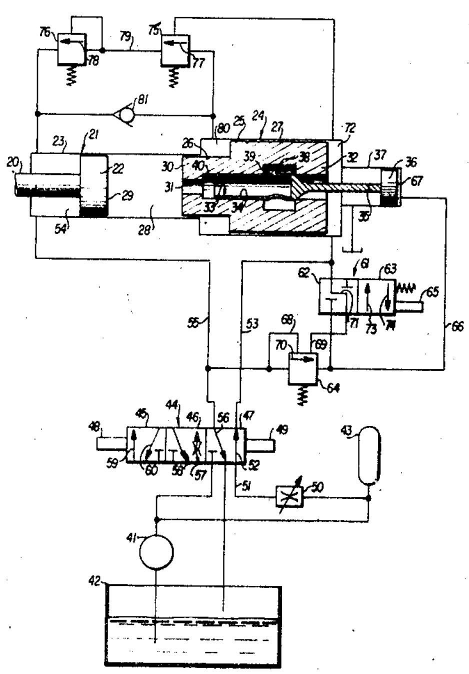
Attorney—Norman F. Oblon et al.

[57] **ABSTRACT**

A die casting machine for casting a molten metal in a mold includes a first piston-cylinder assembly which is operative to cause the molten metal to flow rapidly into the mold and a second piston-cylinder assembly which operates to apply an intensified fluid pressure on a piston surface of the first piston-cylinder assembly when the mold has been filled with the molten metal. The operation of both the first and second piston-cylinder assemblies may be selectively achieved by means of a control valve. The control valve has a piston located in a pressurized working fluid for causing the working fluid to move freely into the first piston-cylinder assembly to pour the molten metal rapidly into the mold during an initial casting process, but the same quickly closes an inlet of the working fluid to the first piston-cylinder assembly when a static pressure difference occurs between the front and rear surfaces of the piston of the control valve upon the mold becoming filled with molten metal, and then the control valve piston causes the working fluid pressure to effectively and quickly be applied on the functional surface of a piston of the second piston-cylinder assembly to generate the intensified pressure to be applied to the molten metal for making a uniform composition.

9 Claims, 5 Drawing Figures



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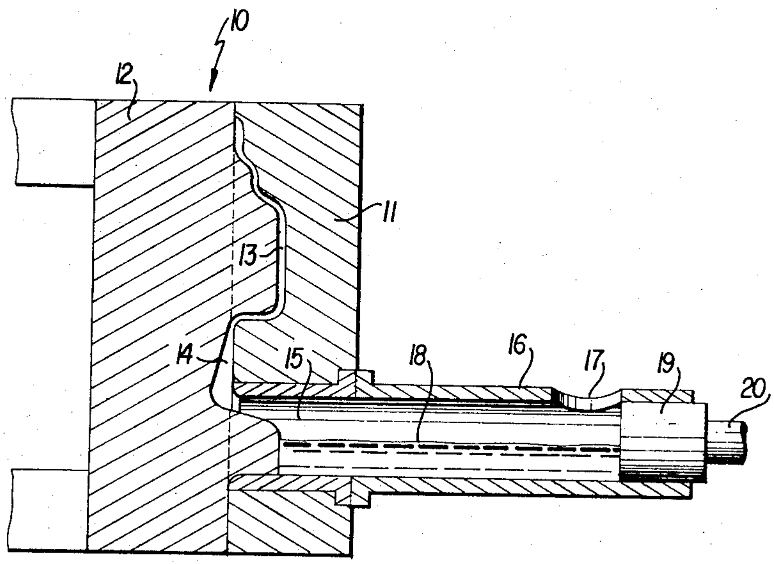

FIG. 1

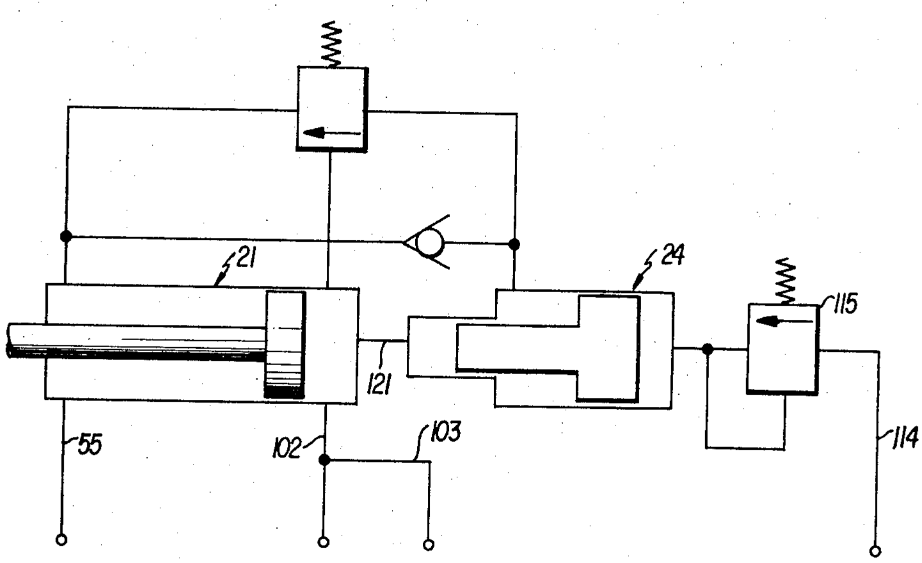

FIG. 5

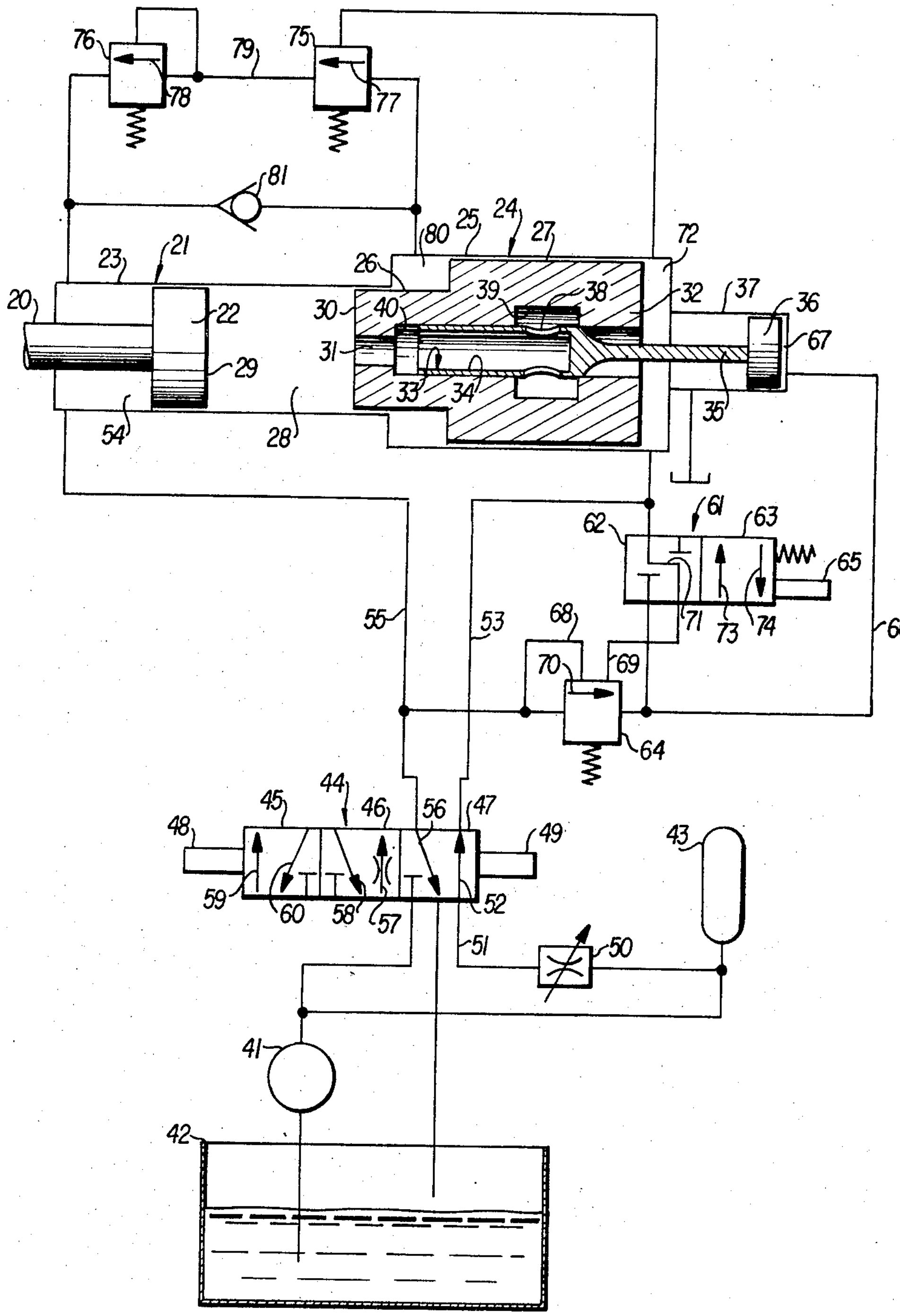
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FIG. 2

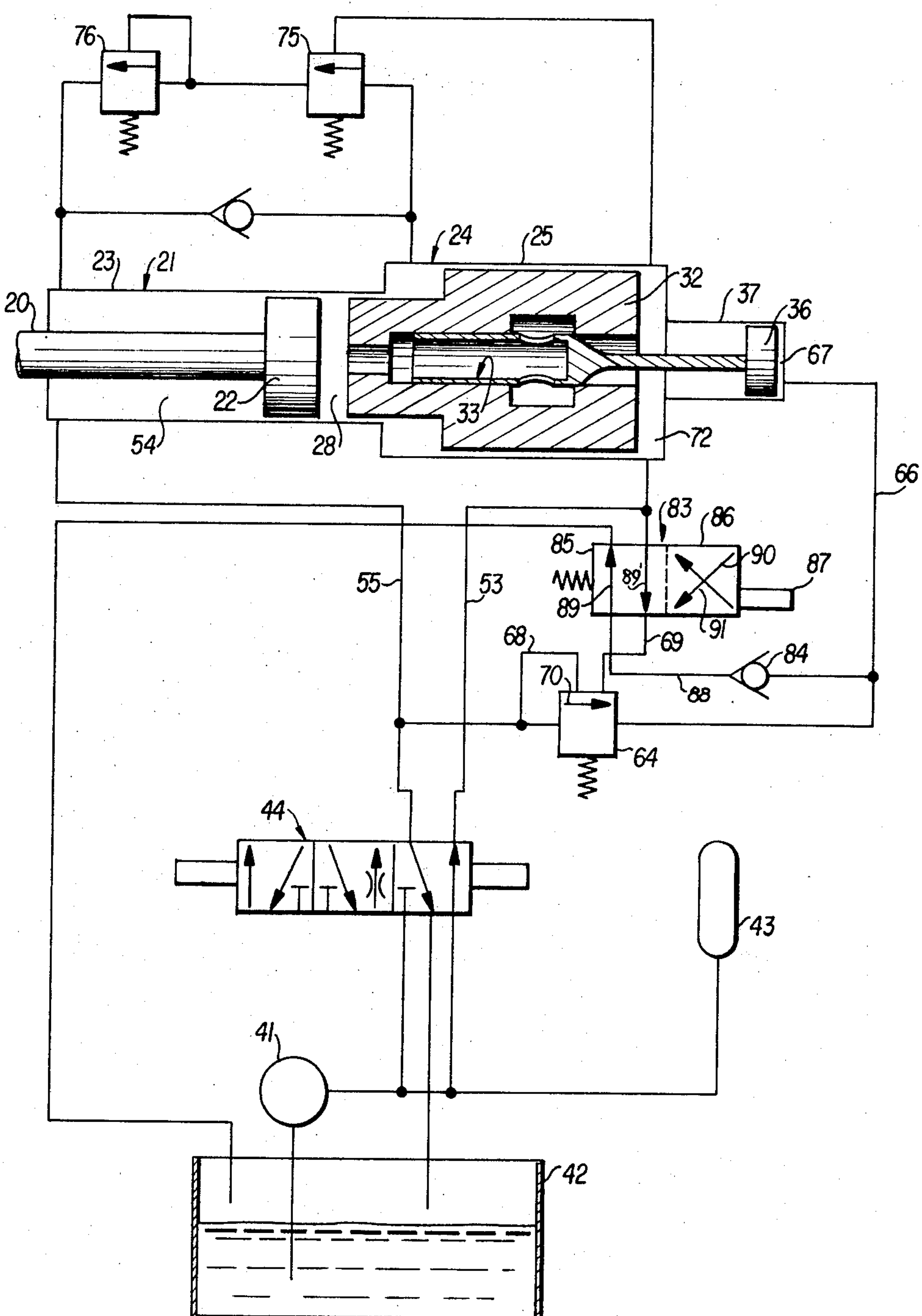
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FIG. 3

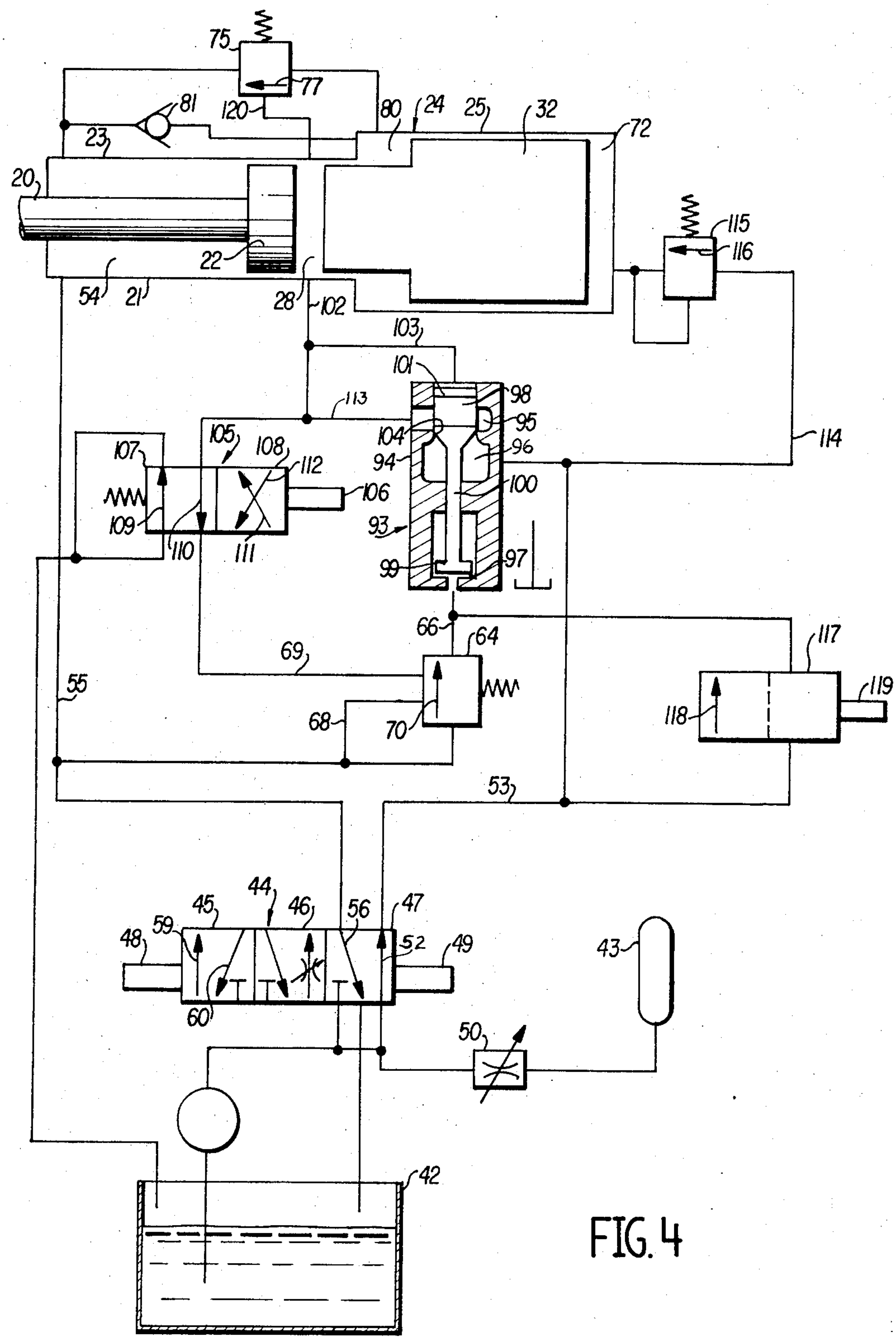
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FIG. 4

PRESSURE INTENSIFYING APPARATUS FOR A DIE CASTING MACHINE

BACKGROUND OF THE INVENTION

1. Field Of The Invention

The present invention relates generally to a pressure intensifying apparatus for a die casting machine and more particularly to such an apparatus for obtaining a cast metal, such as aluminum, zinc, steel and the like, having a uniform composition.

2. Description Of The Prior Art

As is well known in the art, in a die casting process of a metal such as aluminum, zinc, steel and the like, a molten metal is first poured into a mold cavity of a die casting machine, generally through operation of a pushing plunger, and then an intensified pressure is applied to the molten metal located within the cavity of the mold by the pushing plunger to make the composition of the resultant cast metal fine and uniform after the mold has been entirely filled with molten metal.

It is most important in such die casting processes to select the proper time at which the intensified pressure is to be applied to the molten metal that fills the cavity of the mold. If the intensified pressure occurs at a delayed time after pouring the molten metal into the cavity of the mold, the inlet runner or passage of molten metal to the mold cavity may be stopped up by a part of solidified metal to thereby prevent further movement of the molten metal. As a result, the intensified pressure cannot be effectively transferred to the molten metal located in the mold cavity, and thus it is impossible to obtain a cast metal product of high quality and having a fine and uniform composition.

Another problem is that unpreferable results also are obtained if an excessive intensified pressure is applied to the molten metal in the cavity of the mold. This is usually caused by an abnormal function of the pressure control system for the pressure intensifying apparatus, such that a part of the molten metal is expelled from a joint portion between a movable die and a stationary die which cooperate to provide the mold of the die casting machine. Thus, casting fins may undesirably be formed around the cast metal product, which must be removed therefrom by expending much labor and time in order to obtain a cast product of the desired high quality. In addition to treating such a defect, an excessive intensified pressure may also cause the mold to be broken.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved pressure intensifying apparatus for a die casting machine in which an intensifying pressure can be generated at a desired time and without a time delay after filling the mold with molten metal.

Another object of the present invention is to provide a pressure intensifying apparatus for a die casting machine in which an appropriate intensified pressure can be applied to a molten metal located within a mold without danger of breaking the mold.

A further object of the invention is to provide a pressure intensifying apparatus for a die casting machine capable of successfully obtaining cast products of high quality and uniform composition having no casting fins that must be removed therefrom.

The foregoing and other objects are attained, in accordance with the present invention, through the provision of a mold having a cavity for molding metal products therein comprising a pair of die members being relatively separable from each other. An injection sleeve having one end thereof in communication with the mold cavity is provided for injecting an amount of molten metal thereinto. The other end of the injection sleeve has an opening for receiving molten metal and a pusher piston slidably positioned therein for running the molten metal poured into the sleeve into the mold cavity through the one end thereof. There is also provided a first piston-cylinder assembly having a first piston connected to the pusher piston of the injection sleeve through a connecting rod member, the first piston being movable along the cylinder under the pressure of a pressurized working fluid which may be selectively fed to the opposite functional surfaces of the first piston from a pressurized fluid supply. In order to intensify the fluid pressure working on one surface of the first piston, there is provided a second piston-cylinder assembly having a second piston slidably positioned in the cylinder thereof, the second piston having a first land portion of a large diameter and a second land portion of a smaller diameter than the first land portion, both first and second land portions being integrally formed thereon, and the functional surface of the second land portion being in communication with one functional surface of the first piston to transfer an intensified fluid pressure from the former to the latter. There is further provided a control valve means with a non-return valve member, or check valve member, positioned in a pressurized fluid passage, the check valve being operable for first supplying a pressurized fluid to the first piston-cylinder assembly from a pressurized fluid supply to move the first piston rapidly when the mold cavity is being filled with molten metal, and then for stopping the flow of pressurized fluid being supplied to the first piston-cylinder assembly in response to the presence of a static fluid pressure difference between the opposite functional surfaces of the check valve which occurs when the first piston has stopped following the completion of the feeding of molten metal into the mold cavity.

BRIEF DESCRIPTION OF THE DRAWINGS

Various other objects, features and attendant advantages will be more fully appreciated as the same become better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. **1** is an elevational sectional view, being partly broken away, of the mold of a die casting machine;

FIG. **2** is a schematic diagram of one embodiment of a pressure intensifying apparatus for a die casting machine formed in accordance with the present invention;

FIG. **3** is a schematic diagram of another embodiment of a pressure intensifying apparatus formed in accordance with this invention;

FIG. **4** is a schematic diagram of a pressure intensifying apparatus of still another embodiment of the invention; and,

FIG. **5** is a schematic diagram of a pressure intensifying apparatus of a still further embodiment formed in accordance with the invention.

DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Referring now to the drawings, in which like reference numerals designate identical or corresponding parts throughout the several figures, and particularly to FIG. 1 thereof, there is shown a die casting mold generally designated by the reference numeral **10** having a stationary die **11** and a movable die **12**. Dies **11** and **12** are provided with respective recesses on their facing surfaces to form a mold cavity **13** into which molten metal may be poured. The movable die **12** may be moved towards and away from the stationary die **11** by any suitable mechanism of conventional design, not being shown.

When the dies **11** and **12** are closed for carrying out a molding process, a runner **14** is formed between the facing surfaces of the dies to run the molten metal into the cavity **13**. In order to run the molten metal into the cavity **13** through the runner **14**, an opening **15** is provided through the stationary die **11** and a sleeve **16** for feeding molten metal through the opening **15** is also provided, as shown. At one end of the sleeve **16** remote from the stationary die **11** is a radial opening **17** through which an amount of molten metal **18** may be poured into the sleeve **16**. The end of the sleeve **16** is closed by a pusher piston **19** slidably inserted therein which is connected to one end of a piston rod **20** of a pressure intensifier, the description of which follows.

Reference is now made to FIG. 2, wherein a first piston-cylinder assembly generally designated by the reference numeral **21** is shown having a first piston **22** of a relatively small diameter capable of slidable movement along an inside wall of a first cylinder **23** and being connected to the other end of the connecting rod **20**, which, as hereinbefore described, has one end connected to the pusher piston **19** of FIG. 1. There is also provided a second piston-cylinder assembly generally designated by the reference numeral **24** having a second cylinder **25** being larger in diameter than cylinder **23** and connected thereto, and a second or stepped piston **32** having a land portion **26** of a smaller diameter adapted for being slidably inserted in the first cylinder **23** and a land portion **27** of a larger diameter adapted for being slidably inserted in the second cylinder **25**.

In order to supply a pressurized working fluid or oil into a chamber **28** in the cylinder **23** being defined between a front surface **29** of the first piston **22** and the rear surface **30** of the smaller land portion **26** of the second piston **25**, there is provided a through opening **31** axially extending through the second piston **32**, into which a spool-like check valve **33** is slidably inserted. The check valve **33** comprises a tubular portion **34** at one end thereof, an elongate rod or stem **35** extending in one direction from a closed end of the tubular portion **34**, and a terminating piston **36** on the other end of the rod **35** being slidably enclosed in a cylinder **37** having one axial end attached to an axial end of the larger cylinder **25**. The tubular portion **34** of check valve **33** also has at least one transverse through opening **38** near the closed or bottom end thereof, as shown. A bore **39** with an internal diameter larger than the outer diameter of tubular portion **34** is provided in the second piston **32** being axially aligned with the opening **31** and having an axial length sufficient to communicate therethrough within the inside of tubular portion **34** over the entire sliding stroke of the check valve **33**. The leftward position of the check valve **33**, as viewed in FIG. 2, is limited by a stepped portion **40** provided in the opening **31**.

For supplying pressurized working oil, there is provided an oil pump **41** to feed the oil from an oil tank or reservoir **42** into an accumulator **43**, which is hereinafter called a pressurized oil supply. To selectively distribute the pressurized oil from the supply **43** thereof to the several parts of the pressure intensifier, a three-position electromagnetic control valve **44** having first, second and third positions **45**, **46** and **47** is provided, being controlled through the selective energization and deenergization of electromagnetic solenoid coils **48** and **49**.

In the device of FIG. 2, the control valve **44** is shown occupying its third position **47** due to the energization of coil **49**. In this position, pressurized oil fed from the accumulator **43** against the front functional surface of the second piston **32** in the large cylinder **25** through a throttle valve **50**, a conduit **51**, a passage **52** of the third position **47** of control valve **44** and a conduit **53**. Although the detail of the oil passage will be further clarified later in the description, the oil return path may now be roughly traced from the leftward or rear chamber **54** behind the first piston **22** in the first cylinder **23** through a conduit **55**, and through another passage **56** of the third position **47** of control valve **44** to the oil tank **42**.

When the coils **48** and **49** are both deenergized, the control valve **44** assumes its neutral or second position **46**, in which the conduit **53** is connected to the accumulator **43** through a throttle valve **57** of the second stage **46** having a smaller restricted section than that of the throttle valve **50**, and conduit **55** is similarly connected through a passage **58** of the second stage **46** to the tank **42**. The first position **45** of the control valve **44** will be assumed in place of the third stage **47** when coil **48** is energized, and then a passage **59** will connect the accumulator **43** to conduit **55** and a passage **60** will connect conduit **53** to the oil tank **42**. This is used for the return movement of the pressure intensifier, the description of which follows.

In order to control the check valve **33**, a second valve means **6**, having two stages or positions **62** and **63** and an oil pressure responsive valve **64** are provided. The control valve **61** takes the first position **62** when its electromagnetic solenoid coil **65** is deenergized, and takes its second position **63** when the same coil **65** is energized.

The pressure responsive valve **64** is located between conduits **55** and **66**, and one end of the latter conduit **66** opens into a chamber **67** which is defined between the functional surface of the piston **36** and an end wall of the cylinder **37**, as shown. The valve **64** has a pair of control inlets or conduits **68** and **69** for opening and closing the control thereof, being of a conventional type, for example, with a pressure responsive diaphragm and a bias spring acting against the deviation of the diaphragm. If a higher pressure of oil exceeding a predetermined amplitude acts upon the diaphragm through the conduit **69**, the valve **64** allows its passage **70** to communicate the conduit **55** with conduit **66**. On the other hand, if a pressurized oil is conducted from conduit **55** into the conduit **68**, the valve

64 immediately opens the passage 70 to provide communication between conduits 55 and 66 independently of the predetermined pressure amplitude previously described.

When the valve 61 takes its first position 62, the passage 71 allows the conduit 69 to communicate with a chamber 72 being defined between the front surface of the large piston 32 and an end wall of the cylinder 25, thereby causing the pressure responsive valve 64 to respond to the oil pressure in the chamber 72. If the second position 63 of control valve 63 is assumed, its passage 73 makes conduit 66 communicate with chamber 72 of the second piston-cylinder assembly 24 to thereby communicate the chamber 72 with chamber 67 in the cylinder 37, while passage 74 of the second position 63 causes the duct 69 to communicate with the oil tank 42.

In order to obtain a desirable intensifying pressure, there are provided a first pressure-responsive valve, or first control valve, 75 and a second pressure-responsive valve, or second control valve, 76 having respective passages 77 and 78 connected in series through a conduit 79. These valves 75 and 76 have similar construction to valve 64 described above. The inlet of the first valve 75 is connected to a chamber 80 provided between a rear surface of the larger land 27 and the other end wall of the large cylinder 25. The outlet of the second valve 76 is connected with the chamber 54 of the first piston-cylinder assembly 21. The first control valve 75 is controlled under a pressure of oil within chamber 72 of the large cylinder 25, and responds to a predetermined pressure value of the oil to open the passage 77 thereof. The second control valve 76 causes the section of passage 78 thereof to be regulated responsive to a predetermined pressure rise of oil in the duct 79, and conducts the oil in chamber 80 into chamber 54. There is also provided a check valve 81 across the pair of valves 75 and 76 such that the oil cannot flow therethrough in a leftward direction, as seen in FIG. 2, but the oil can flow easily therethrough in the rightward direction.

Prior to describing the operation of the device, let us assume that chambers 28, 72, 80, 67 and other parts, with the exception of chamber 54, are filled with oil, and check valve 33 is in the most leftward position being stopped by stepped portion 40 in the opening 31, while valves 64 and 75 close their passages 70 and 77, and control valve 61 is in the first position 62, as shown. Also assuming that dies 12 and 11 have been closed and the piston 19 has been withdrawn to the most rightward position in the sleeve 16 for the provision of die casting. An amount of molten metal 18 is then poured into sleeve 16 through the opening 17. Both electromagnetic coils 48 and 49 of the control valve 44 are deenergized in order to communicate passages 57 and 58 of the second position 46, thereof with conduits 53 and 55, respectively, as shown.

The pressurized oil from accumulator 43 is thus introduced into chamber 72 through the throttle valve 50, conduit 51, throttle valve 57 having a section smaller than that of valve 50, and duct 53. Then the working oil enters freely into chamber 28 through openings 38 of the check valve 33 being located at its open position and the opening 31 so that the first piston 22 will begin its movement slowly to the left along with the pusher rod 20. It will be easily understood that this slow forward movement of the piston 22 results from the smaller cross-section of the passage 57 of the control valve 44.

Pusher rod 20 then drives the piston 19 slowly leftward to move the molten metal 18 towards runner 14 and then pours molten metal into the cavity 13. When the pusher rod 20 advances over a predetermined distance, a limit switch, not shown, causes the coil 49 to be energized so as to bring the third position 47 of the control valve 44 to its functional position in place of the second position 46. Thus, the narrower passage 57 is removed from the oil flow passage, and passage 52 communicates duct 51 with duct 53 to feed a relatively larger amount of working oil from the accumulator 43 into the chamber 28 through throttle valve 50, conduit 51, passage 52, duct 53, chamber 72, openings 38 of the check valve 33 and the opening 31. As a result, the first piston 22 can be more quickly moved leftward along with its pusher rod 20 and piston 19. The molten metal 18 will thus rush into the cavity 13 through the runner 14 to rapidly fill the cavity with molten metal.

It is understood, when pouring of molten metal into cavity 13 is intended, that the forward movement of piston 22 as described is entirely free, because the chamber 54 at the rear side of the piston 22 is open to the tank 42 through conduit 55 and passage 58 or through conduit 55 and passage 56.

When the cavity 13 in mold 10 is completely filled with molten metal 18, pistons 19 and 22 and the connecting pusher rod 20 will quickly come to a stop, and thereby oil pressure in the chambers 72, 28, opening 31 and bore 39 will suddenly increase.

In response to a predetermined amplitude of oil pressure rise in the chamber 72, pressure-responsive valve 64 allows its passage 70 to be opened under the oil pressure being transferred from chamber 72 into the valve 64 through passage 71 of valve 61 and conduit 69. Thus, the chamber 67 in front of piston 36 is brought into communication with tank 42 through conduit 66, passage 70 of pressure-responsive valve 64, conduit 55 and passage 56 of three-position valve 44, thereby allowing oil that has filled chamber 67 to be exhausted freely into the oil tank 42.

It will be clearly understood that the static oil pressures in chamber 28, opening 31, bore 39 and chamber 72 will become equal anywhere to each other immediately upon stopping the oil flow, as described above. Looking now at the closed or bottom portion of tubular portion 34 of the spool-like check valve 33, in which the front or rightward function surface has a pressure receiving area less than the rear or leftward function surface of the bottom of the tubular portion 34 by an amount equal to the cross-section of stem 35, it is evident that a force will occur operating to move the check valve 33 to the right, due to the difference between these pressure-receiving areas.

The check valve 33 immediately moves rightward to close off the right side opening of bore 39 with the bottom portion of tubular portion 34 thereof. Thereafter, oil flow intended for entry into chamber 28 through the opening 31 will be effectively shut off. The oil pressure rise in chamber 72 is also immediately transferred to the first pressure-responsive valve 75 causing it to open when the pressure rise overcomes the setting pressure amplitude. When the valve **75** opens, the passage **77** communicates conduit **79** with the chamber **80** being defined around land **26** of the stepped piston **32**.

Thus the stepped piston **32** begins to move leftward under the increased oil pressure in chamber **72**, and at the same time the oil in chamber **80** is pressed by the end wall of the land **27**, increasing its pressure, and this oil is then conducted into conduit **79** through the passage **77** of the control valve **75**. Thus, the second pressure-responsive valve or the second pressure-control valve **76** functions to regulate a cross section of its passage **78** to maintain the pressure of oil in chamber **80** at a predetermined level. The oil leaving valve **76** is then exhausted in oil tank **42** through chamber **54**, conduit **55** and passage **56** of three-position control valve **44**.

The stepped piston **32** can now be moved leftward responsive to a pressure difference between chambers **72** and **80** to establish an intensified oil pressure in the chamber **28**. This intensified oil pressure is added to the function surface of the first piston **22**, then is added to the molten metal filling the mold cavity **13** through the pusher rod **20** and piston **19** so that the resultant cast product being obtained will possess a fine and uniform composition.

An examination of the prior art indicates that the most simple construction of the check valve **33** would be a spool-like one with a coiled bias spring positioned in a tubular portion **34**. These check valves were not provided with portions such as the stem **35** and piston **36**. The bias spring was provided with one end seated on stepped portion **40** in the opening **31** and the other end seated on the bottom tubular portion **34** of check valve **33**. It was found that it was very difficult to determine the biasing force of the spring for the following reasons.

If the biasing force of the spring is made to be low, the pressurized oil easily enters the chamber **28** by pushing the check valve forward against the spring bias to push the first piston **22** forward with rod **20** in a rapid manner, but once the piston **22** is stopped by filling of the cavity **13** with molten metal, the opening **31** is closed slowly due to the weak spring force. As a result, oil flow would continue through opening **31** towards chamber **28**, so that the time at which the pressure intensifying function by the second piston **32** occurs is unpreferably delayed, whereby solidification of the molten metal **18** may occur at the runner **14** to prevent the intensified pressure being caused by the second piston-cylinder assembly **24** from being effectively transferred to the molten metal in the cavity **13**. This obviously causes cast products to be produced having rough and non-uniform composition.

In addition, there is another time delay inherent in the conventional die casting machines, which depends upon the amount of molten metal in the cavity **13** and the compressibility thereof, the elastic compressibility of the pusher rod **20**, pistons **19**, **22** and **32**, and the working oil as well. It can be seen that this time delay cannot be removed because these factors are dependent on the size and material of casting products and the material to be used for manufacturing the various parts of the die casting machine. Accordingly, the aforesaid time delay depending upon the spring coefficient of the check valve **33** should be reduced to be as small as possible to emanate an intensified pressure increase at an appropriate time.

In order to reduce the time delay resulting from the use of a spring-biased check valve, consideration was given to increasing the strength of the coiled spring. However, this method showed an undesired result in that the check valve **33** could not open the opening **31** sufficiently to allow the oil flow to enter the chamber **28** easily when the rapid movement of the pusher rod **20** was required for pouring molten metal into the mold cavity **13**. In this way the molten metal in cavity **13** might be solidified before the intensified pressure rise took place.

In experiments conducted, there also sometimes occurred a wider opening of the passage **78** of the pressure-responsive valve **76** for the reason of overshooting thereof. This was caused for the following reason. When a coiled biasing spring of weak strength was used in the tubular check valve **33** and an oil pressure rise occurred in chamber **28**, if the check valve **33** could not simultaneously close the opening **31**, the second piston **32** could go forward with a high speed since there was less load on the second piston **32** due to the still open opening **31**, such that an abnormal pressure rise might take place in chamber **80** of the larger cylinder **25** to cause the passage **78** of valve **76** to open widely, exceeding a desired sectional area. This might cause an excessive intensified pressure to be added to the molten metal in mold cavity **13**, and accordingly a part of the molten metal would be expelled out of the matched surfaces of the mold dies **11** and **12** to produce undesirable cast fins on the product which in turn must be removed from the cast products by expending much labor. Additionally, the mold **10** was apparently exposed to a danger of breakage due to the excessive intensified pressure. It was thus required to manufacture a very strong die casting machine at high cost.

It will be easily understood from the previously described embodiment of this invention that the identified defects of the prior devices just discussed can be reduced satisfactorily by the present invention. In other words, the die casting machine of this invention has no spring-biased check valve. The check valve **33** can be moved to close the opening **31** under a pressure difference that may be caused by a difference of size between front and back surfaces of a bottom portion of the tubular member **34** of check valve **33**. The closing operation of the check valve **33** may occur at an earlier time or as soon as movement of the pusher rod **20** has been stopped due to the molten metal filling the mold cavity **13**. Actually, the check valve **33** closes communication between the chambers **28** and **72** before the second piston **32** starts its leftward movement for pressure-intensifying purposes. Thus, no overshooting of the pressure-responsive valve **76** may occur, and it is possible to obtain the most preferable intensified pressure for applying to the molten metal in the mold cavity **13** to manufacture cast products having fine and uniform composition and without having cast fins.

When the molten metal has been solidified in the mold cavity **13**, solenoid coil **65** of the two-position control valve **61** is energized by any suitable timer relay, not shown, and the first position **62** is then replaced by the second position **63**. In this way, passage

73 of second position 63 causes the chamber 72 to communicate with the chamber 67 of cylinder 37 through passage 73 and conduit 66, and passage 74 releases the control oil of pressure-responsive valve 64 towards oil tank 42 through conduit 69, to bring the passage 70 thereof to a closed position. As a result, a pressurized oil is introduced from chamber 72 into chamber 67 to advance the piston 36 forward along with tubular portion 34 and stem 35 of check valve 33 to reopen the opening 31 of stepped piston 32. The pressurized oil from accumulator 43 is again supplied into chamber 28 to advance the first piston 22 forward along with pusher rod 20 and piston 19, and accordingly solidified molten metal 18 left in the sleeve 16 is pushed out of the left end of the sleeve 16 when the movable die 12 is moved away from the stationary die 11.

After the solidified metal is removed from the inside of sleeve 16, coil 65 is deenergized to reset the control valve 61 to a position, as shown, and then solenoid coil 48 of the three-position control valve 44 is energized. The first position 45 thus comes to its working position to communicate conduit 55 with accumulator 43 through passage 59 and to communicate conduit 53 with the oil tank 42 through passage 60. The pressurized oil from accumulator 43 is supplied into chamber 54 through the passage 59 and conduit 55 and the oil in chamber 72 may be exhausted therefrom into the oil tank 42.

At the same time, the pressurized oil in conduit 55 is added to the pressure-responsive valve 64 through conduit 68 to communicate conduit 55 with conduit 66 through passage 70 therein. In this case, the control valve 64 is so made that the passage 70 thereof is easily opened at a lower pressure than that being received from conduit 69. This is easily achieved by providing a larger pressure function area for oil to be entered through conduit 68 than that for oil from conduit 69. Accordingly, the pressurized oil from accumulator 43 is also supplied into chamber 67 to fill the same with oil so long as the conduit 55 is connected to the accumulator 43. The check valve 33 is thus held in a position such that the opening 31 is open to bore 39 through opening 38 so that chambers 28 and 72 are communicated with each other freely through the opening 31.

The first piston 22 then moves to the right under the pressure of the pressurized oil being supplied to the chamber 54, and the oil in chamber 28 is exhausted into tank 42 through opening 31 of stepped piston 32, openings 38 of the check valve 33, chamber 72 in cylinder 25, conduit 53 and passage 60 of the three-position control valve 44. The oil in chamber 54 is also fed into chamber 80 around the smaller land portion 26 of stepped piston 32 through check valve 81. Of course both pressure-responsive valves 75 and 76 close their passages 77 and 78 at this time. Thus the first piston 22 is returned towards its initial position, and the stepped piston 32 is also returned rightward towards its initial position.

All the parts of the die casting machine are therefore returned to their initial positions, respectively, and are ready for a succeeding die casting operation.

FIG. 3 shows another embodiment of the invention that is nearly the same as that of FIG. 2, except for an arrangement including a second control valve 83 and a check valve 84, replacing control valve 61. The second control valve 83 also has two stages or positions, the first being designated by the numeral 85 and the second by 86, with the former one 85 being as indicated when an electromagnetic solenoid coil 87 is deenergized, and being replaced by the latter one 86 when the coil 87 is energized. Check valve 84 is located between the conduits 66 and 88 so that oil flow can take place only in a direction from conduit 88 to conduit 66.

Upon the quick feeding of the piston 22 together with its pusher rod 20 for pouring molten metal into mold cavity 13, the control valve 83 takes its first position 85, as shown, to communicate chamber 72 of cylinder 25 with conduit 69 through passage 89'. In this case, passage 89 of the first position 85 of check valve 83 communicates conduit 88 with oil tank 42, but the check valve 84 does not allow oil flow to take place therethrough. As described above, since chamber 67 is filled with oil to position the spool-like check valve 33 at its most leftward position, pressurized oil from accumulator 43 is supplied into chamber 28 through conduit 53, chamber 72 and opening 31 of the piston 32.

As in the first embodiment described before, oil flow directed from chamber 72 to chamber 28 will stop suddenly as soon as the piston 22 stops upon completion of pouring molten metal into the cavity 13, whereby the static oil pressure will increase in chambers 28 and 72 to move the spool-like check valve 33 rapidly to the right to close the opening 31. This can be achieved by communication between conduits 66 and 55 through the passage 70 of the pressure-responsive valve 64 which in turn responds to the increased static pressure in chamber 72 through passage 89' and conduit 69.

In order to expel metal solidified in the sleeve 16 after solidification of molten metal in the cavity 13, coil 87 is energized to change the valve 83 from its first position 85 to its second position 86. The pressurized oil is then supplied from conduit 53 through passage 90 and check valve 84 into chamber 67 to move the spool-like check valve 33 leftward, and the same is freely flown into chamber 28 through chamber 72 and opening 31 to move the first piston 22 leftward together with its pusher rod 20, while passage 91 releases the pressure applied on the control valve 64 through conduit 69 and to the oil tank 42 to reset passage 70 for shutting off communication between conduits 55 and 66.

FIG. 4 shows still another embodiment of the invention, in which a spool-like check valve assembly generally designated by a reference numeral 93 has been taken outside of the stepped piston 32.

The check valve assembly 93 comprises a cylinder 94 having three tandem chambers 95, 96 and 97, a piston 98 slidably arranged in the chamber 95, another piston 99 slidably arranged in the chamber 97 and a connecting rod 100 connecting the pistons 98 and 99 to each other and extending therebetween. At the top of the cylinder 94, there is provided a further chamber 101 communicating with the chamber 28 of the first piston-cylinder assembly 21 between the piston 22 and the piston 32 through conduits 102 and 103, and the upper portion of piston 98 is slidably enclosed in the chamber 101. The chamber 95 has a valve seat 104 on which the piston 98 can be seated or removed therefrom.

An electromagnetically operable two-position control valve 105 is provided, being similar to valve 61 of the embodiment shown in FIG. 2, and having a solenoid coil **106** and first and second positions **107** and **108**. The first position **107** of valve **105** has two passages **109** and **110**, similarly the second position **108** has two passages **111** and **112**, and the valve takes a position as shown so long as the coil **106** is deenergized. When the coil **106** is energized, the first position **107** is replaced by the second position **108** as the active position.

Chamber **95** is connected to a control inlet of pressure-responsive valve **64** in a manner similar to that of the embodiment shown in FIG. **2** through conduit **113**, passage **110** of control valve **105** and conduit **69**. Another control inlet for the valve **64** is connected to conduit **55** through conduit **68** also in the same manner as that of FIG. **2**. Chamber **96** of check valve **93** is connected to the chamber **72** in front of the second piston **32** through conduit **114** and pressure-responsive valve **115**. The valve **115** is controlled under the pressure of pressurized oil in chamber **72** and communicates chamber **72** through passage **116** with conduit **114** so as to regulate the oil pressure in chamber **72** to a predetermined amplitude. Chamber **96** of check valve **93** is also connected to conduit **53**, which in turn is connected to the control valve **44** and related devices as described by reference to FIG. 2.

In order to effect a forward feed of the first piston **22** along with its pusher rod **20** for expelling the metal solidified in sleeve **16** of FIG. **1**, there is provided an electromagnetically controllable valve **117** having a passage **118** which is brought to a position where conduit **66** is communicated with conduit **53** when a solenoid coil **119** is energized.

More particularly, in accordance with this embodiment, a pressure control oil inlet of pressure-responsive control valve **75** is connected to the chamber **28** in the first piston-cylinder assembly **21**.

In operation, it is assumed that the chamber **97** in front of the piston **99** of spool-like check valve **93** is filled with an amount of working oil, and piston **99** is pushed upward together with piston **98** and rod **100**. In this way, pressurized oil from accumulator **43** is fed into chamber **28** through conduit **102**, chamber **95**, valve seat **104**, chamber **96**, conduit **53** and passage **52** of three-position valve **44** so that the piston **22** is advanced forwardly along with rod **20** for feeding molten metal rapidly into the mold cavity **13**.

When the mold cavity **13** has been filled with molten metal, the motion of piston **22** stops so that oil pressure in chamber **28** rapidly increases to a value substantially equal to that of accumulator **43**. Oil flow stoppage also occurs in chamber **95** and **96** of spool-like check valve **93** to develop an equal static oil pressure on both end surfaces of piston **98**.

Since the lower end surface of piston **98** has a smaller pressure-receiving area than the upper one thereof by an amount equal to the cross-section of rod **100**, the piston **98** is moved downward in response to the pressure difference thereon and is seated on the valve seat **104** to shut off the oil flow therethrough.

On the other the other hand, the pressurized oil in chamber **28** also operates on the pressure-responsive valve **64** through conduits **102** and **113**, passage **110** of valve **105** and conduit **69** to communicate the chamber **97** below the piston **99** with conduit **55** through its passage **70** and conduit **66**, so that oil in the chamber **97** is released to oil tank **42** to allow the downward movement of the piston **98**.

Further, the increased oil pressure in chamber **28** operates on pressure-responsive valve **75** through conduit **120** to allow the passage **77** to communicate chamber **80** in the cylinder **25** of the second piston-cylinder cylinder assembly **24** with chamber **54** in cylinder **23** of the first piston-cylinder assembly **21**, and then with oil tank **42** through conduit **55** and passage **56** of the three-position control valve **44**. Thus, the larger piston **32** can be now moved leftward. At the same time, the pressurized oil is fed from accumulator **43** into chamber **72** in front of the piston **32** through throttle valve **50**, passage **52** of valve **44**, conduits **53** and **114** and passage **116** of pressure regulation valve **115**. Thus, working oil regulated to a desired amplitude by the pressure regulation valve **115** is fed into chamber **72** so that the piston **32** can provide a desired intensified oil pressure to be added to the molten metal in cavity **13**, as described by reference to FIG. 2.

After solidification of the molten metal in the mold cavity **13**, the mold **10** is opened to take out the cast product, and then solenoid coil **119** of control valve **117** is energized to feed working oil from accumulator **43** into chamber **97** below the piston **99** through passage **118** of the valve **117**. Thus the spool-like check valve **93** opens its valve seat **104** again to feed working oil into chamber **28** through conduit **53**, chambers **96** and **95** and conduit **102**, so that the piston **22** is advanced forwardly along with pusher rod **20** in order to remove the solidified metal from the sleeve **16**.

Next, coil **106** of control valve **105** is energized to communicate the chamber **95** of valve **93** with tank **42** through passage **112** to thereby discharge oil in the chamber **28** into oil tank **42**, as well as to communicate conduit **69** with tank **42** through passage **111** to reset the pressure-responsive valve **64**. Thus, the piston **22** can be moved freely to the right.

The coil **119** is deenergized, and then coil **48** of the three-position control valve **44** is energized so that the third position **47** of the valve **44** is replaced by the first position **45** as the active position. Pressurized working oil is then fed from accumulator **43** into chamber **54** through passage **59** and conduit **55**. From conduit **55** a part of the working oil is conducted to conduit **68** so that the passage **70** of valve **64** is actuated to allow conduits **66** and **55** to communicate with each other. As a result, piston **99** again rises to remove piston **98** from its seat **104** so that the oil in chamber **28** can be exhausted into tank **42** through conduit **102**, chambers **95** and **96** of valve **93**, conduit **53** and passage **60** of the three-position valve **44**. Thus the piston **22** is returned rightward towards its initial position. A further part of the oil can be taken from chamber **54** into chamber **80** through check valve **81** so that the stepped piston **32** is returned towards its rightward initial position.

All the parts of the die casting machine are thus returned to their initial positions for permitting a succeeding die casting process to be carried out.

It can be seen that the same objects and features as those of FIGS. 2 and 3 can be achieved by the embodiment described by reference to FIG. 4. Additionally, since the spool-like check valve **93** is located outside the stepped piston **32**, manufacture of the stepped piston **32** and the check valve **93** is made much easier without requiring alignment of the parts.

FIG. **5** shows a still further embodiment of the invention, in which the first piston-cylinder assembly **21** and the second piston-cylinder assembly **24** are made separately and are connected to each other through a conduit **121**, as shown. In accordance with this arrangement, the piston-cylinder assembly **24** can be located freely at a position remote from the first assembly **21** so that there may be obtained much more freedom in the manufacture and building of the die casting machine.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. Pressure intensifying apparatus for a die casting machine comprising:

A mold having relatively separable dies facing each other and defining a mold cavity therebetween for receiving molten metal for making a cast product;

a sleeve member having one end thereof connected to said mold for feeding an amount of molten metal into said cavity;

a first piston-cylinder assembly having a first cylinder slidably receiving a first piston, another piston slidably disposed in said sleeve for forcing molten metal therefrom and into said mold cavity, and a pusher rod having one end connected to the first piston and extending from one end of the first cylinder and its other end connected to said another piston in said sleeve;

a second piston-cylinder assembly having a second piston and a second cylinder slidably receiving said second piston, said second piston being formed with a first land portion and a second land portion of greater diameter than the first land portion and said second cylinder being provided with a first portion substantially equal in diameter to said first land portion being slidably disposed therein and a second portion substantially equal in diameter to said second land portion being slidably disposed therein and a chamber in said first portion of said second cylinder on one side of said first land portion being open to said first cylinder on the first piston side thereof so as to enable a fluid pressure to be transmitted from said chamber of said second cylinder onto a functional surface of said first piston;

means for feeding a working fluid into first cylinder on the first piston side thereof comprising a spool-like check valve member positioned in said working fluid to allow said working fluid to flow into said first cylinder to move said first piston so as to feed molten metal into the mold cavity, said check valve including axially opposed end surfaces having different pressure-receiving surface areas so that the check valve shuts off the feeding of working fluid into said first piston side of said first cylinder in response to a sudden increase in pressure of the working fluid therein which occurs when the movement of said first piston has been stopped by the filling of said mold cavity with molten metal; and,

means for applying a regulated fluid pressure on the functional surfaces of said second land portion of said second piston to remove a desired intensified pressure from the second piston when said spool-like check valve shuts off working fluid flowing into the first piston side of said first cylinder.

2. Pressure intensifying apparatus for a die casting machine according to claim **1**, wherein:

said second piston of second piston-cylinder assembly is provided with an axially extending through opening for flowing a working fluid therethrough and a bore provided at an intermediate position along the longitudinal axis of the opening, said bore having a larger internal diameter than that of the opening; and,

said spool-like check valve includes a tubular portion slidably located in said through opening having an open end facing towards the functional surface of said first piston, a closed bottom opposite said open end, and at least one radial opening through which the working fluid can flow, a stem member extending from the bottom of said tubular portion longitudinally through said through opening and end wall of second cylinder of said second piston-cylinder assembly, and a piston mounted on the end of said stem being slidably received in an additional cylinder mounted on said end wall of said second piston-cylinder assembly,

said spool-like check valve being capable of movement along said through opening by a defined stroke so that said radial opening of the tubular portion thereof is always exposed in said bore over the entire stroke of said check valve, one of the axially opposite surfaces of said bottom of the tubular portion having a larger pressure-receiving surface area than the other surface by an amount equal to the cross-section of said stem so that a pressure difference resulting therefrom causes said check valve to close said through opening in a direction depending upon the pressure difference when a static fluid pressure is developed on the bottom, and said piston being mounted on the end of said stem causing said bottom of said tubular portion to move away from its closed portion to open said through opening when a working fluid is supplied onto the functional surface thereof in said additional cylinder.

3. Pressure intensifying apparatus for a die casting machine according to claim **1**, further comprising:

a spring-biased fluid back pressure control valve connected in series with a passage for exhausting fluid from a chamber defined by a stepped portion of said second piston between said land portions and said second cylinder so that a predetermined intensified fluid pressure can be provided by said second piston-cylinder assembly.

4. Pressure intensifying apparatus for a die casting machine according to claim **2**, further comprising:

a pressure-responsive valve connected with said second cylinder and said additional cylinder and being responsive to a sudden increase in pressure of the working fluid in a chamber in front of said second piston so that a working fluid filling a chamber in front of said piston in said additional cylinder may be exhausted from the additional cylinder to allow movement of the piston therein to close said through opening in said second piston.

5. Pressure intensifying apparatus for a die casting machine according to claim 1, wherein:

said first cylinder of said first piston-cylinder assembly has its one open end directly connected to an open end of said second cylinder of said second piston-cylinder assembly, and the open end of said first cylinder is provided with a portion having a diameter substantially equal to that of said first land portion of the second piston for slidably receiving the same.

6. Pressure intensifying apparatus for a die casting machine according to claim 1, wherein said spool-like check valve member comprises:

a cylinder having first, second, third and fourth chambers arranged in tandem therein, the second chamber having an opening with a valve seat for fluidly connecting the second chamber with the third chamber therethrough, and first and second pistons connected to each other through a piston rod, a part of said first piston being slidably received in said first chamber, said first piston being also provided with opposing first and second fluid function surfaces, the second surface having a smaller area that the first surface by an amount substantially equal to the cross-section area of said piston rod and a shape suitable for seating on said valve seat of the second chamber to shut off said opening against fluid flow therethrough; and,

said first and second chambers are communicated with a chamber in front of said first piston of said first piston-cylinder assembly, said third chamber is connected to a pressurized fluid supply, and said fourth chamber may be connected to the fluid supply when required for causing said first piston of said check valve to open said valve seat and is released when a pressurized fluid is supplied from the supply to said third chamber.

7. Pressure intensifying apparatus for a die casting machine according to claim 1, wherein:

said second piston of said piston-cylinder assembly is of solid construction, said spool-like check valve member is located outside of said second piston, and a pressure control valve is positioned in an upward stream of the working fluid that flows into a chamber of the second cylinder in front of said second piston to thereby generate a desirable intensified pressure from said second piston-cylinder assembly in response to the pressure of the working fluid in said chamber.

8. Pressure intensifying apparatus for a die casting machine according to claim 1, wherein:

said first and second piston-cylinder assemblies are spaced apart and are connected through conduit means for transferring an intensified fluid pressure from the second piston-cylinder assembly to the first piston-cylinder assembly.

9. Pressure intensifying apparatus for a die casting machine comprising:

a mold having relatively separable dies facing each other and defining a mold cavity therebetween for receiving molten metal for making a cast product;

a sleeve member having one end thereof connected to said mold for feeding an amount of molten metal into said cavity;

first piston transfer means having a part thereof slidably disposed in said sleeve for feeding said molten metal therefrom and into said cavity;

second piston transfer means for supplying fluid under pressure to said first piston transfer means for moving the same in one direction;

a spool-like check valve member in said second piston transfer means for selectively permitting flow therethrough and preventing fluid flow therethrough; and,

fluid flow control means for positioning said check valve to permit fluid flow therethrough to operate said first piston transfer means and upon filling said mold cavity being responsive for positioning said check valve to prevent further flow through said second piston transfer means, and further for subsequently operating said second piston transfer means to intensify the pressure of said fluid acting upon said first piston transfer means.

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