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VARIABLE COMPRESSION RATIO PISTON

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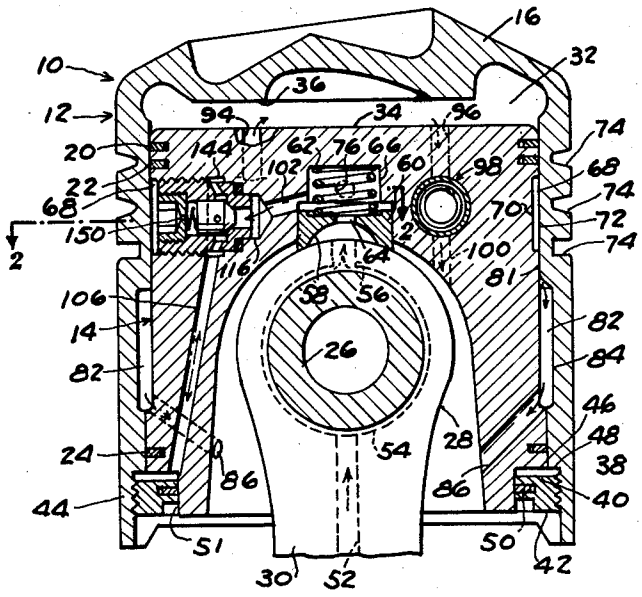
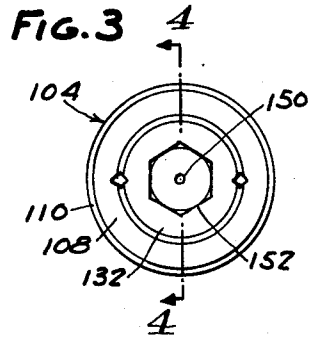


FIG. 1



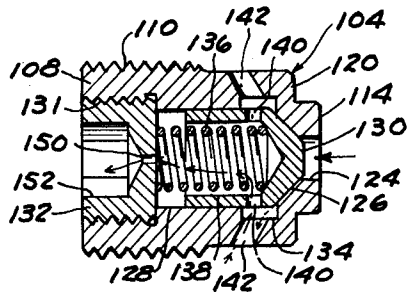
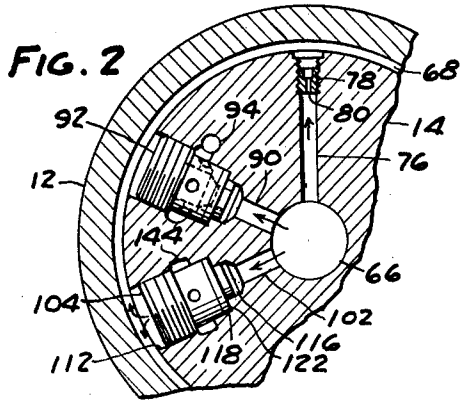


FIG. 4



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VARIABLE COMPRESSION RATIO PISTON

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This invention relates to improvements in variable compression ratio (VCR) pistons of the type disclosed in U.S. Patents Nos. 2,742,027, dated April 17, 1956, 3,014,468, dated Dec. 26, 1961 and 3,038,458, dated June 12, 1962, all issued in the name of Wilfred P. Mansfield. More particularly, the present invention relates to improvements in the means for controlling flow of an incompressible fluid, such as oil, to and from a chamber in a VCR piston to thereby control movement of one part of the piston relative to another.

The present invention is particularly directed to the problem of providing a controlled discharge of oil at a restricted rate from the lower chamber of a two-part VCR piston, such as that disclosed in the aforesaid Mansfield 2,742,027 patent. In one form of the Mansfield VCR piston, an inner piston is connected in the usual manner to a connecting rod and carries an outer piston which is adapted to move axially to a limited extent relative to the inner piston. Clearance spaces are provided between the top and bottom ends of the inner and outer pistons which form upper and lower variable volume chambers adapted to contain an incompressible fluid such as oil. By controlling the flow of oil to and from these chambers, the movement of the outer piston relative to the inner piston in response to piston reciprocation and combustion chamber pressure is controlled for varying the clearance volume of the cylinder in which the piston reciprocates, as set forth in more detail in the aforesaid Mansfield patents.

However, the known methods of controlling discharge of oil from the lower chamber, such as a fixed or an adjustable restricted orifice which discharges oil directly to crankcase atmosphere, have been found to suffer from a common problem, namely that of crankcase gas bubbles being sucked through the discharge passage into the lower chamber when the volume thereof is increased. This condition is undesirable since accuracy of control and even operation of the VCR piston itself depends upon maintaining the upper and lower chambers filled with an incompressible as opposed to a compressible fluid. Once gas finds its way into the chamber, an uncontrollable spongy action results instead of a positive, hydraulically controlled movement of the outer piston relative to the inner piston.

It is an object of the present invention to provide an improved VCR piston in which discharge of oil or other compressible fluid from a variable volume chamber therein is controlled by a flow restriction in a manner which overcomes the aforementioned problem of air entrainment in the chamber.

Another object is to provide an improved VCR piston of the above character having a cooling chamber through which the incompressible control fluid is circulated to internally cool the piston and which is connected in a simplified manner with the variable volume chamber for preventing back bleed of compressible fluid thereto and for augmenting the supply of fluid to said cooling chamber.

A further object is to provide an improved valve assembly for use in a VCR piston which is adapted to control both supply of incompressible fluid to and the discharge of such fluid from a variable volume control chamber of the piston.

A more particular object is to provide in a VCR piston of the upper and lower chamber type an improved control fluid circuit for the lower chamber which provides for internal cooling of the piston, prevents back bleed of compressible fluid into the lower chamber and simplified construction of the piston.

Other objects, features and advantages of the present invention will become apparent from the following description taken in conjunction with the accompanying drawing wherein:

FIG. 1 is a vertical section through the axis of an improved VCR piston constructed in accordance with the present invention.

FIG. 2 is a fragmentary sectional view taken on the line 2—2 of FIG. 1 with upper and lower chamber supply valves shown in elevation.

FIG. 3 is an enlarged and elevational view of an improved valve assembly of the invention.

FIG. 4 is a vertical section taken on the line 4—4 of FIG. 3.

Referring to FIG. 1, there is shown by way of example a preferred embodiment of a VCR piston 10 adapted for reciprocation in the bore of a cylinder of a four-stroke cycle internal combustion engine. Piston 10 comprises an outer piston 12 which is carried on an inner piston 14. Outer piston 12 has a crown 16 which serves as the head of piston 10 and forms the movable wall of the cylinder combustion chamber. Inner piston 14 is slidable within and axially of outer piston 12 and carries rings 20, 22 and 24 which have a fluid sealing engagement with the outer piston. Inner piston 14 is attached in a conventional manner by a wrist pin 26 to the upper end 28 of a connecting rod 30. An upper variable volume chamber 32 for containing control fluid is formed between the upper surface 34 of inner piston 14 and the interior surface 36 of crown 16. A lower variable volume chamber 38 for containing control fluid is defined by the annular space between the upper surface 40 of a retaining ring 42 which is threadably secured in the skirt 44 of outer piston 12 and the shoulders 46 and 48 of inner and outer pistons 14 and 12 respectively. A sealing ring 50 is carried in a groove of ring 42 and has a fluid sealing, sliding engagement with a reduced diameter portion 51 of inner piston 14.

Due to the clearance spaces provided by chambers 32 and 38, outer piston 12 can move downwardly (as viewed in FIG. 1) relative to inner piston 14 until crown surface 36 abuts upper surface 34 of the inner piston, and the outer piston can move upwardly relative to the inner piston until ring 42 abuts shoulder 46 of the inner piston. This movement of the outer piston is controlled by automatically regulating the flow of an incompressible control fluid into and out of chambers 32 and 38. The control fluid preferably comprises oil supplied to piston 10 from the usual pressurized lubricating oil supply of the engine via an oil passage 52 in rod 30. Passage 52 communicates at its lower end with a crankshaft oil supply passage (not shown) and runs upwardly to the upper end 28 of the rod where it communicates with an annular groove 54 encircling wrist pin 26 and leading to an outlet 56. Oil under engine lubricating pressure flows upwardly via passages 52, 54 and 56 into a cavity 58 of a cap 60 which is urged downwardly by a spring 62 into sliding sealed engagement with the upper end 28 of rod 30. The oil then passes through an axial hole 64 in cap 60 into a spring chamber 66 from which the flow of oil branches into three separate flow paths leading respectively to the upper chamber 32, the lower chamber 38 and an annular cooling chamber 68.

Cooling chamber 68 is defined by an annular external groove 70 formed in inner piston 14 and by an inner wall 72 of outer piston 12, groove 70 being located adjacent the external ring grooves 74 of the outer piston.

Referring to FIG. 2, oil is fed from chamber 66 to cooling chamber 68 by a radial passage 76 in which is threadably secured a metering plug 78 having a calibrated through-passage 80. Oil is discharged downwardly from chamber 68 via the annular clearance space 81 (FIG. 1) between inner piston 14 and wall 72 to a larger annular chamber 82 defined by an internal groove 84 in outer piston 12 and by the adjacent exterior of the inner piston. Downwardly inclined passages 86 in inner piston 14 drain oil from chamber 82 to the crankcase sump of the engine.

Oil is fed from chamber 66 to upper chamber 32 by a second radial passage 90 (FIG. 2) which communicates via a one-way check valve 92 and a passage 94 with chamber 32 (FIG. 1). Oil is discharged from chamber 32 through a passage 96 under the control of a pressure regulating discharge valve 98 which opens to release oil to a drainage passage 100 when oil pressure in chamber 32 exceeds a predetermined value.

Oil is fed from chamber 66 to the lower chamber 38 via a third radial passage 102 (FIGS. 1 and 2) which leads to a combination inlet and discharge valve assembly 104 of the present invention. Valve 104 controls the supply of oil to and from a combination supply and discharge passage 106 running downwardly in inner piston 14 from the valve 104 to chamber 38.

As best seen in FIGS. 3 and 4, valve 104 comprises a cylindrical casing 108 having threads 110 for screwing the valve assembly into a threaded bore 112 which extends from cooling groove 70 radially into inner piston 14 and intersects passages 102 and 106. A reduced diameter nose 114 of casing 108 projects into a counterbore 116, and a sealing gasket 118 (FIG. 2) is clamped between a shoulder 120 (FIG. 4) of casing 108 and a shoulder 122 at the inner end of bore 112. Internally, casing 108 has an axial inlet passage 124 with a chamfered valve seat 126 at the inner end thereof, a larger diameter bore 128 in which a bullet-shaped valve member 130 is slidably received for axial movement therein, and a still larger diameter bore 131 in which an end-plug 132 is thredably secured. The nose of valve member 130 seats in fluid tight engagement against seat 126 to thereby close communication between inlet 124 and an internal annular groove 134 formed in bore 128 adjacent seat 126. A light compression coil spring 136 at one end abuts plug 132 and at the other abuts the blind end of a bore 138 in valve member 130 to bias it towards seat 126. Two or more radial ports 140 in valve member 130 provide communication between bore 138 and groove 134. Casing 108 likewise has two or more radial ports 142 connecting groove 134 with an annular groove 144 (FIG. 1) formed in inner piston 14 and communicating with passage 106.

It is to be noted that in accordance with the present invention, plug 132 is provided with a restricted orifice 150 (FIGS. 3 and 4) which opens into an Allen wrench socket 152 in the plug. Orifice 150 restricts the flow of oil from the valve chamber formed by bores 128 and 138 to the reservoir of oil present in cooling chamber 68. Ports 140 and groove 134 are located and dimensioned relative to one another to that communication always exists between the valve chamber and lower chamber 38 via passage 106 whether or not valve member 130 is closed or open.

Operation

Assume that combustion chamber pressure is below a predetermined maximum value which VCR piston 10 is designed to maintain, and that upper and lower chambers 32 and 38 are both filled with oil. As inner piston 14 decelerates in approaching top dead center position at the end of the exhaust stroke and then accelerates in the opposite direction on the intake stroke, the momentum of outer piston 12 tends to force it upwardly relative to inner piston 14, thereby raising the oil pressure in lower chamber 38 above that existing in spring chamber 66 and passage 102. The maximum lower chamber pressure at this time may range somewhere between 500 and 1000 p.s.i., as compared to a pressure of 200–250 lbs. p.s.i. in supply chamber 66, depending upon engine speed.

The oil pressure in lower chamber 38 is transmitted via the column of oil in passage 106 to the body of oil contained in the valve chamber. Thus, as ring 42 is forced upwardly by outer piston momentum, oil pressure behind valve member 130 builds up until it, plus the pressure of spring 136, overbalances the oppositely acting force exerted by the pressure oil in the supply chamber 66 on the area of valve member 130 exposed in inlet 124, forcing the valve member against seat 126 to thereby close communication between chambers 38 and 66. Thereafter, as lower chamber pressure peaks, a predetermined amount of oil is forced out of chamber 38 via passage 106, ports 142 and 140 to the interior of valve member 130, and then through restricted orifice 150 to cooling chamber 68 from which it leaks as previously described.

The controlled leakage of a predetermined amount of oil from lower chamber 38 permits outer piston 12 to move a very small distance (a few thousandths of an inch) upwardly relative to inner piston 14. This in turn increases the volume of, and consequently reduces fluid pressure in, upper chamber 32. When oil pressure in passage 99 (FIG. 2) exceeds that in chamber 32, valve 92 opens to admit oil from supply chamber 66 to chamber 32. This oil is trapped in chamber 32 when valve 92 closes due to reversal of the pressure differential between chambers 32 and 66 upon reversal of momentum forces as piston 10 approaches and passes through the bottom dead center position at the end of the intake stroke and at the beginning of the compression stroke.

The trapped oil prevents outer piston 12 from moving back downwardly relative to the inner piston until such time as the oil pressure in chamber 32 exceeds the predetermined pressure at which regulating valve 98 is set to open against the pressure of its spring. Hence upward movement of the outer piston 12 relative to inner piston 14 may occur for several cycles, terminating when the cylinder clearance volume has been reduced to the point where combustion chamber pressure reaches the predetermined maximum value which produces the valve-opening pressure in chamber 32. Thereafter a state of relative equilibrium exists wherein the outer piston moves upon and down very slightly relative to the inner piston in each cycle, its mean relative position being that producing the maximum combustion chamber pressure as predetermined by the setting of valve 98.

If the combustion chamber pressure is suddenly increased, as by opening the engine throttle or increasing the load on the engine, valve 98 is designed to rapidly discharge oil from upper chamber 32 so that outer piston 12 can move downwardly relative to inner piston 14, thereby increasing the cylinder clearance volume and thus reducing combustion chamber pressure to the desired maximum value. Valve 98 is designed to permit outer piston 12 to move downwardly more rapidly than restricted orifice 150 permits it to move upwardly in each cycle. This insures rapid relief of excessive combustion chamber pressure and limits oil pumping losses since the outer piston must gradually "creep" back up to regain its original position relative to the inner piston.

The downward movement of outer piston 12 relative to inner piston 14 increases the volume of lower chamber 38, causing the oil pressure therein to drop to some value between 150 p.s.i. and zero p.s.i., or even to a negative pressure. As lower chamber pressure drops, the oil pressure behind valve member 130 is relieved via ports 140 and 142, permitting it to open against the light pressure (e.g., about 2 ounces) of spring 136 as soon as the pressure in passage 106 falls sufficiently below that in passage 102. Oil from chamber 66 then flows via passage 102 and inlet 124, past the space between valve member 130 and valve seat 126, through groove 134, ports 142 and passage 106 to thereby supply lower

chamber 38 with the required volume of oil to satisfy the pressure conditions.

It is to be noted that as the foregoing pressure reversal begins to occur, tending to create a partial vacuum in lower chamber 38, that chamber 38 is isolated from crankcase gases by the column of oil present in passage 106. This is in contrast to the prior arrangement wherein a regulating orifice in ring 42 was directly exposed to crankcase gases. In the prior arrangement, rapid downward movement of outer piston 12 would increase the volume of chamber 38 and suck in gases from the crankcase before a flow of oil from chamber 66 could be established. The present invention precludes this happening.

Supplemental to the isolating effect of the column of oil in passage 106, a small amount of oil may bleed back from cooling chamber 68 to chamber 38 via restricted orifice 150, valve member 130, ports 140 and passage 106 since this bleed path is always open. However, this does not cause bleed of compressible gases back into chamber 38 since orifice 150 is isolated from the crankcase gas by the relatively large quantity of constantly circulating oil in cooling chamber 68. The cooling oil leaks in sufficient quantity downwardly from chamber 68 through clearance space 81 to provide an oil seal against such gases entering the cooling chamber.

It will be apparent from the foregoing description that the present invention provides an improved oil supply and discharge circuit for controlling the quantity of oil in lower chamber 38 which overcomes the aforementioned problem of air entrainment in lower chamber 38 while retaining the advantages of a restricted orifice flow control, such as low manufacturing and maintenance cost and freedom from wear problems. Also, the need for a separate discharge passage from lower chamber 38 is eliminated since passage 106 serves as a common inlet and outlet passage for the lower chamber. In addition, the oil discharge from lower chamber 38 via restricted orifice 150 is utilized to advantage in supplementing the oil supply to cooling chamber 68. Another advantage is that a substantial duplicate of valve assembly 104 may be used as the supply valve 92 for upper chamber 32, the only difference being that restricted orifice 150 is omitted from valve 92, thereby simplifying construction of piston 10.

It is to be understood that the diameter of restricted orifice 150 (about .025 inch for the particular piston 10 illustrated herein) may be varied in accordance with known design practice to suit the particular pressure conditions encountered as well as the requirements of the particular size piston employed to thereby provide the desired regulation of upward movement of outer piston 12 relative to inner piston 14.

We claim:

1. In a variable compression ratio piston for an internal combustion engine comprising first and second parts movable relative to one another in response to reciprocation of the piston, said parts defining first and second fluid chambers within said piston which vary in internal volume oppositely to one another in response to said relative movement and to variations in the quantity of fluid therein, a supply passage adapted to receive an incompressible fluid under pressure from a source external to the piston, first and second inlet passages communicating between said supply passage and said first and second chambers respectively, non-return valve means permitting one-way flow of fluid through said first and second passages towards said first and second chambers respectively, a first discharge passage leading from said first chamber to the exterior of said piston, a pressure regulating discharge valve controlling flow of fluid from said first chamber through said first discharge passage and means for regulating discharge of fluid at a restricted rate from said second chamber including a third chamber in said piston normally flooded with said pressure fluid from said supply passage and a flow connection adapted for draining fluid from said third chamber to the exterior of the piston.

2. The combination set forth in claim 1 wherein said third chamber comprises an annulus in said piston supplied with fluid from said supply passage for cooling said piston.

3. The combination set forth in claim 1 wherein said second inlet and discharge passages have a common portion between said second chamber and said non-return valve means therefor, said second chamber non-return valve means being adapted to permit one-way flow from said supply passage to said common portion of said passages and to permit flow at a restricted rate from said common portion to said third chamber.

4. The combination set forth in claim 3 wherein said second chamber non-return valve means comprises a valve casing having relatively unrestricted passage therein adapted to connect said second inlet passage with said common portion of said second passages, said casing having a valve seat in said casing passage and a bore aligned with said valve seat, a valve member movable in said bore and co-operable with said seat to open and close communication between said second inlet passage and said common portion of said second passages, a plug in said bore remote from said seat, a spring in said bore between said valve member and plug for biasing said valve member towards said seat, said plug having a restricted orifice for connecting said casing bore with said third chamber, and means connecting said casing bore on the plug side of said valve member with said common portion of said second passages.

5. In a variable compression ratio piston adapted for operation in an internal combustion engine comprising first and second parts movable relative to one another in response to reciprocation of the piston and defining first and second liquid chambers therebetween which vary in internal volume as a result of said relative movement and in an opposite sense relative to one another, means for unidirectionally supplying liquid to said first chamber, means including a pressure regulating valve for controlling discharge of the liquid from said first chamber for regulating said relative movement in one direction, means for unidirectionally supplying liquid to said second chamber, and means including a restricted orifice for controlling discharge of the liquid from said second chamber for regulating relative movement in a direction opposite to said one direction; the combination therewith of means in said piston including a third chamber having an inlet communicating with sad orifice and an outlet communicating with the exterior of said piston, said third chamber being continuously flooded with liquid between said inlet and outlet thereof to thereby isolate said second chamber from gaseous fluid to which the piston is exposed in the engine.

6. In a variable compression ratio piston having an internal chamber formed therein which varies in volume as a result of pressure regulating movement of said piston, a hydraulic control circuit comprising a source of liquid under pressure, means in said piston defining a supply passage communicating with said source and said chamber, a check valve in said passage operable to permit unidirectional flow from said source to said chamber, and means for conducting liquid from said chamber to the exterior of said piston including a restricted orifice communicating with said chamber and a second chamber in said piston having an inlet communicating with said orifice and having an outlet communicating with the exterior of said piston, and means in said piston for supplying liquid to said second chamber to maintain it continuously filled with liquid to thereby provide a liquid barrier between said first chamber and the exterior of the piston.

7. The hydraulic circuit set forth in claim 6 wherein said last mentioned means comprises a passage in said

piston leading from said source to said second chamber and having a flow capacity greater than said restricted orifice, said second chamber being arranged such that the flow of liquid thereinto from said inlet and branch passage circulates in cooling relation therethrough to said outlet for cooling the piston.

8. The hydraulic circuit set forth in claim 6 wherein said valve and restricted orifice are disposed adjacent one another remote from said first chamber, said piston having a combination inlet and outlet passage for said first chamber communicating at one end with said first chamber and at the other end with said valve and orifice, said inlet and outlet passage being normally filled with liquid to thereby provide a supplemental liquid barrier between said first chamber and the exterior of said piston.

No references cited.