# United States Patent [19]

**Zimmerman**

[11] **3,871,340**

[45] **Mar. 18, 1975**


[54] **ROTARY VALVE INTERNAL COMBUSTION ENGINE**


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[73] Assignee: **Tetrahedron Associates, Incorporated,** San Diego, Calif.



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[21] Appl. No.: **294,573**

[52] **U.S. Cl.** .. **123/80 BA,** 123/190 BD, 123/190 E, 184/10

[51] **Int. Cl.** ..... **F011 7/16**

[58] **Field of Search**.... 123/190 BD, 190 B, 190 BB, 123/190 E, 190 DL, 80 BA; 184/10, 6.16



[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 1,278,083 | 9/1918 | Force | 123/190 BD |
| 1,296,124 | 3/1919 | Schettler | 123/41.33 |
| 1,363,894 | 12/1920 | Molstad | 123/190 BD |
| 1,509,939 | 9/1924 | Elkin | 92/94 X |
| 1,521,842 | 1/1925 | Sprague et al. | 123/190 BB |
| 1,573,022 | 2/1926 | Wehr | 123/190 BD |
| 1,754,019 | 4/1930 | Holmes | 123/190 BB |
| 1,774,713 | 9/1930 | Jahn et al. | 123/190 E |
| 1,782,389 | 11/1930 | Rauha et al. | 123/190 BB |
| 2,038,830 | 4/1936 | Cross | 123/190 BD |
| 2,048,134 | 7/1936 | Montalto | 123/190 BD |
| 2,158,386 | 5/1939 | Sykes | 123/190 BD |
| 2,859,980 | 9/1958 | Zimmerman | 123/80 BA X |
| 2,989,955 | 6/1961 | Dunne | 123/190 BC X |
| 3,405,701 | 10/1968 | Mealin et al. | 123/190 B |

FOREIGN PATENTS OR APPLICATIONS

| | | | |
|---|---|---|---|
| 224,071 | 11/1924 | United Kingdom | 123/190 BD |
| 288,495 | 9/1931 | Italy | 123/190 BD |
| 747,540 | 4/1956 | United Kingdom | 123/190 BD |
| 449,919 | 7/1936 | United Kingdom | 123/190 BD |



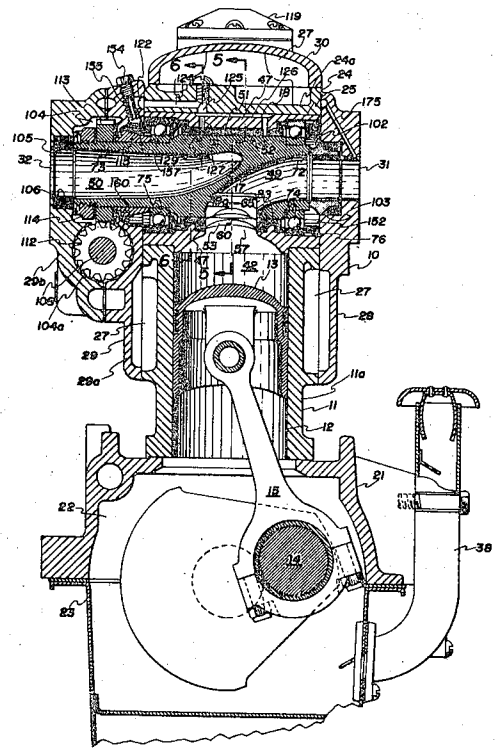
*Primary Examiner*—Charles J. Myhre
*Assistant Examiner*—W. Rutledge, Jr.



[57] **ABSTRACT**

A rotary valve internal combustion engine, in which the feeding of a lubricant to the valves is controlled during low throttle and closed throttle operation of the engine by gas pressure supply means associated with the valve or valves so as to modify the feeding action of the lubricant supply means and further controlled by a lubricant metering valve device automatically responsive to varying load conditions of the engine; the valve bore being self-adjusting with respect to the running fit of the rotary valve therewith so that the valve functions in a highly efficient manner maintaining low operating temperature and with minimum friction and wear.


**28 Claims, 24 Drawing Figures**



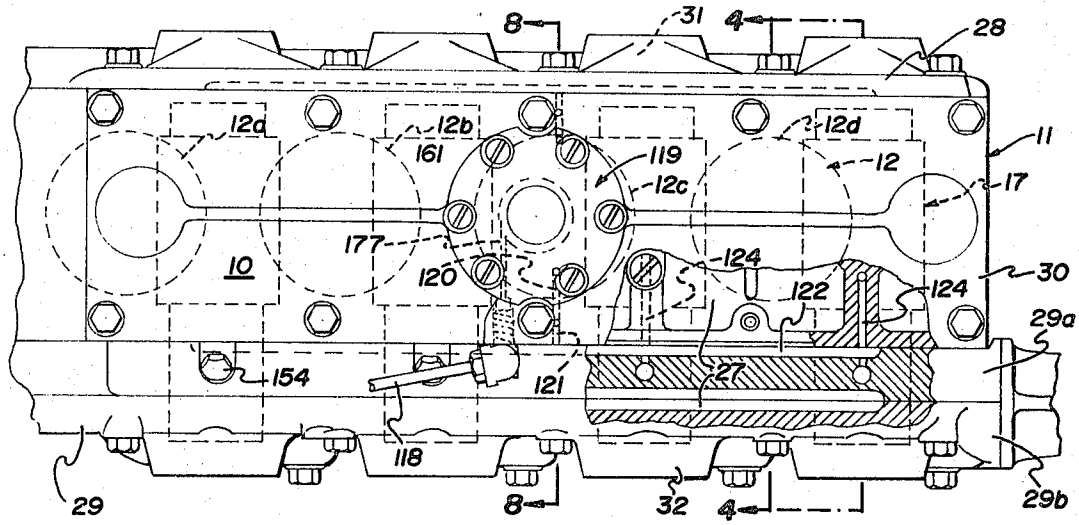



Fig. 1

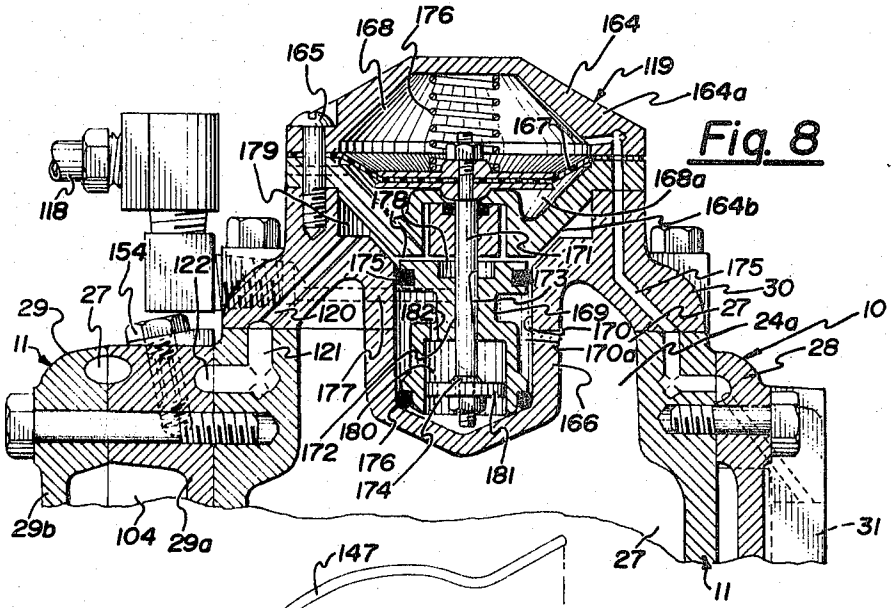



Fig. 8

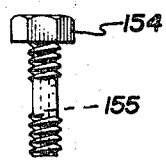



Fig. 22

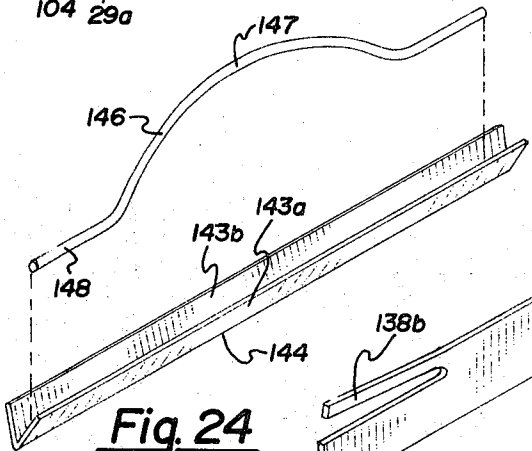



Fig. 24

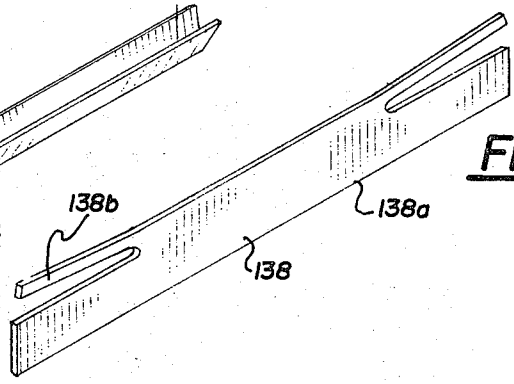



Fig. 23

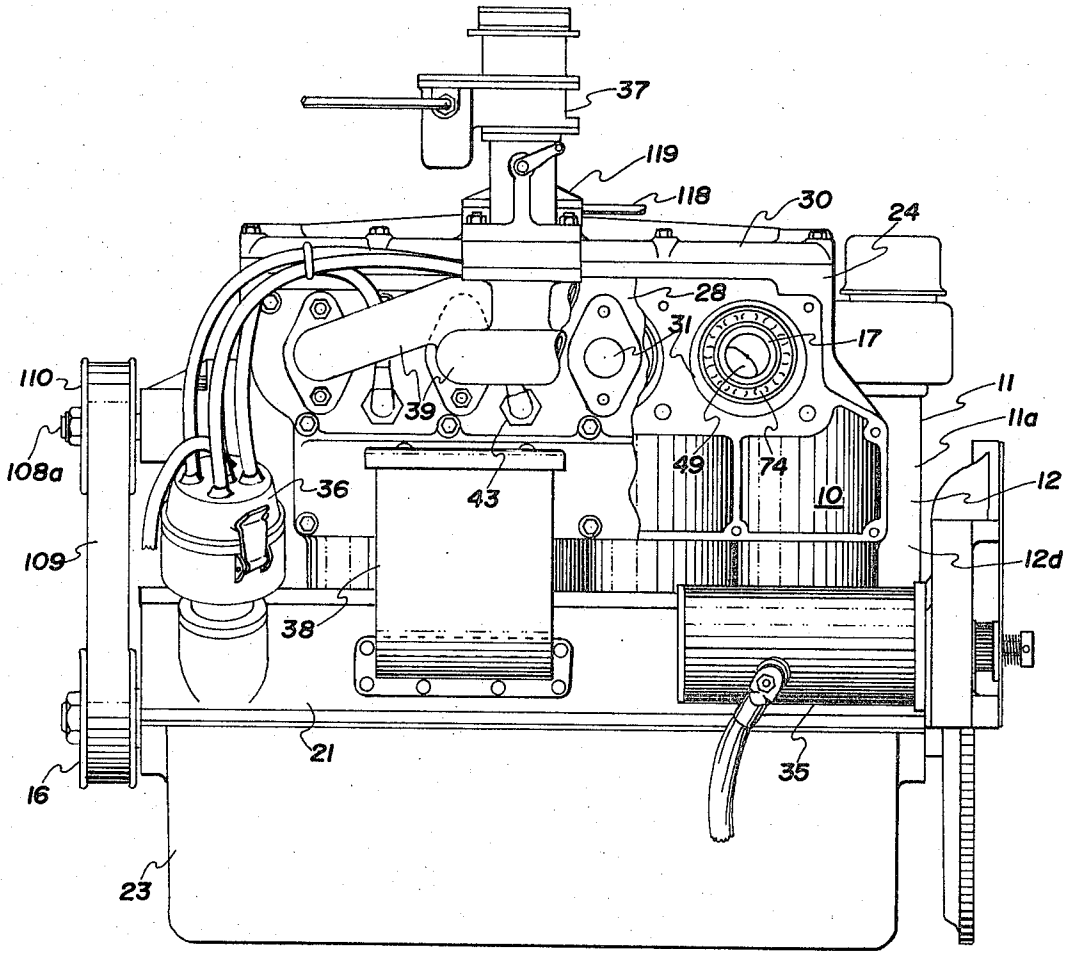

37
119
118
30
24
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31
17
11
11a
110
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108a
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43
49
74
10
12
12d
109
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35
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Fig. 2

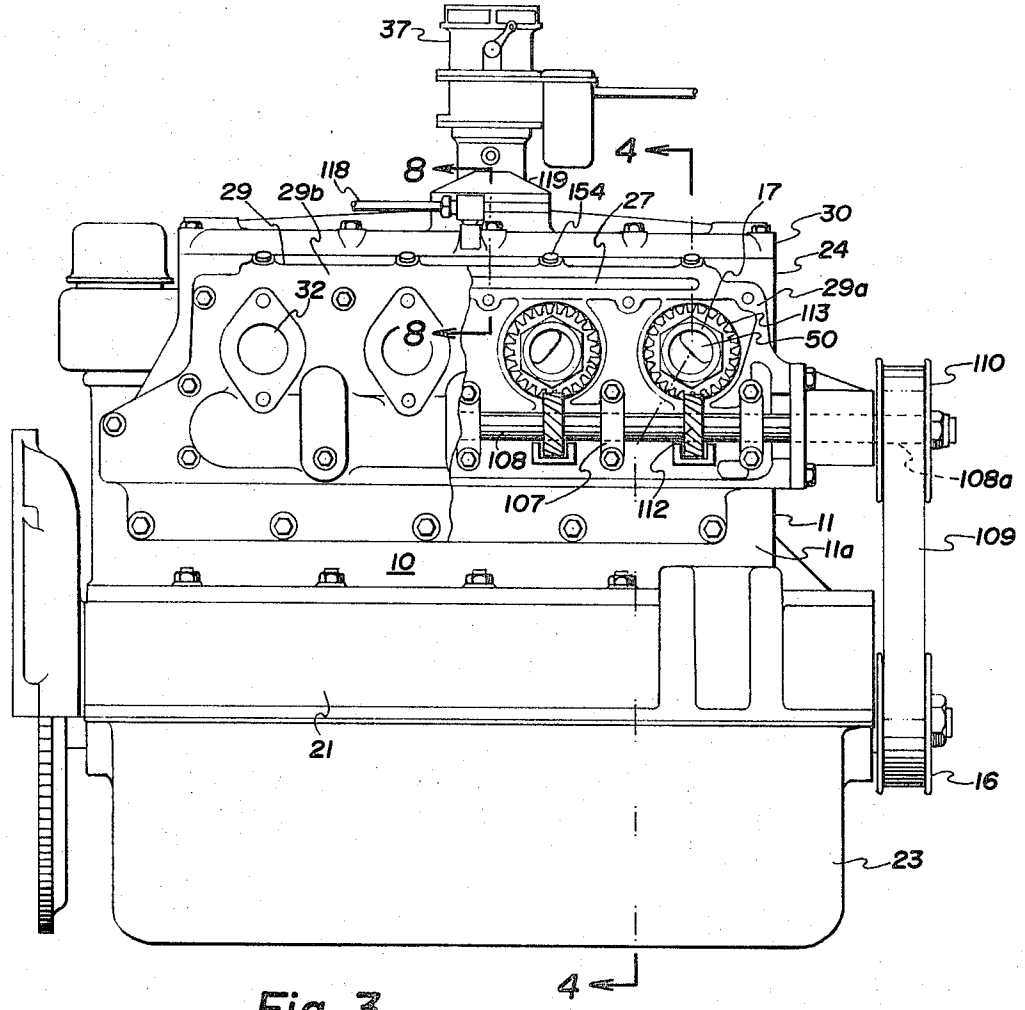
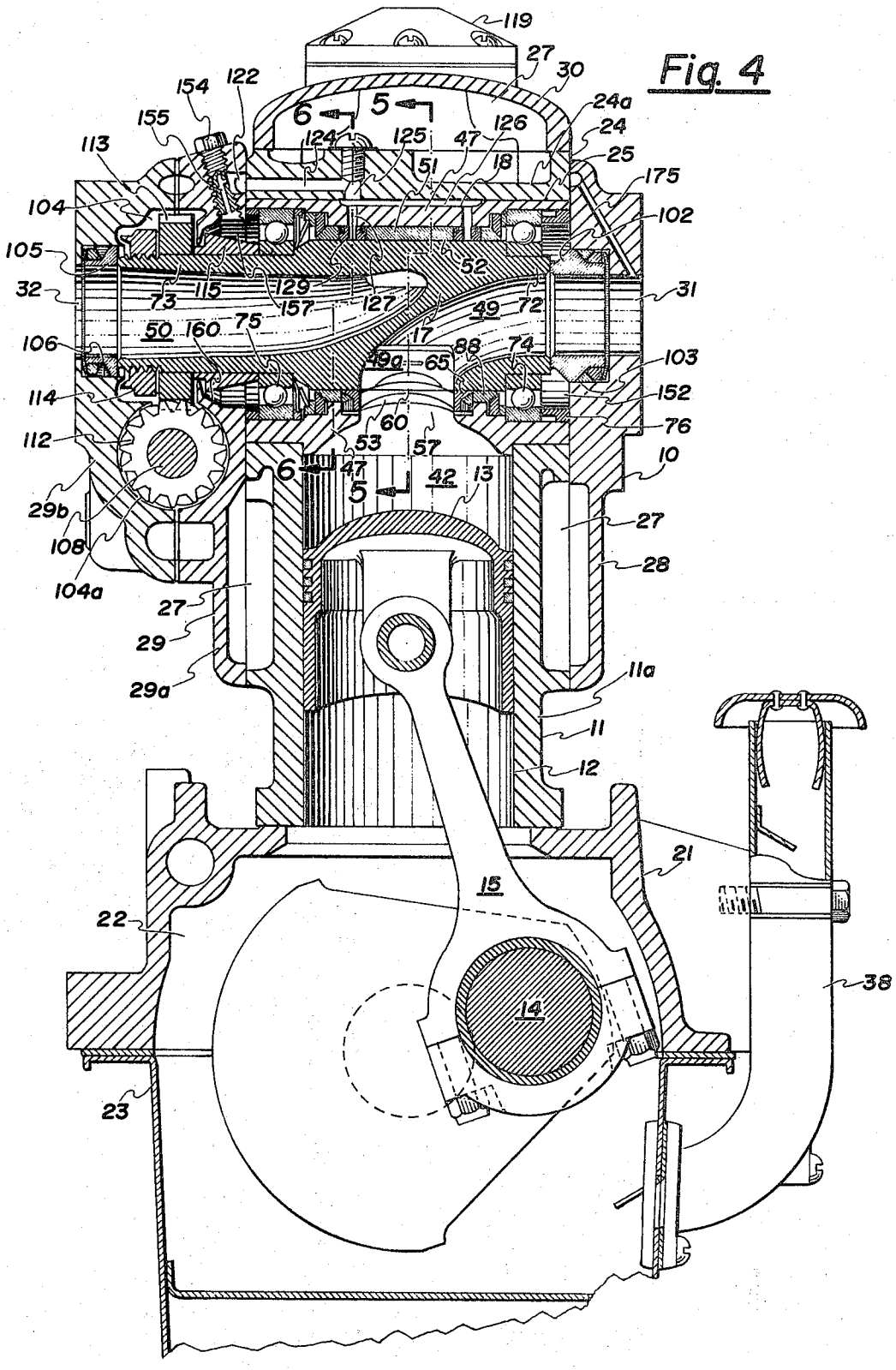

37
4
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118
119
154
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24
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29b
29a
32
113
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110
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108a
107
112
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11a
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21
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23
4

Fig. 3

Fig. 4


119
27
30
24a
24
25
175
102
31
103
152
76
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27
28
11a
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29b
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104a
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29a
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49a
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57
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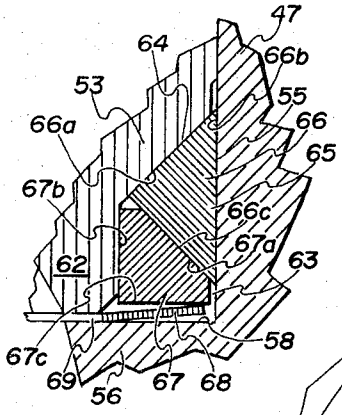



Fig. 9




Fig. 5

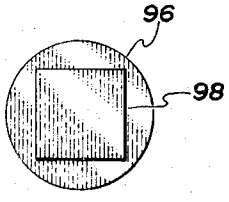



Fig. 19

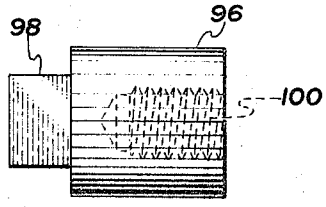



Fig. 18

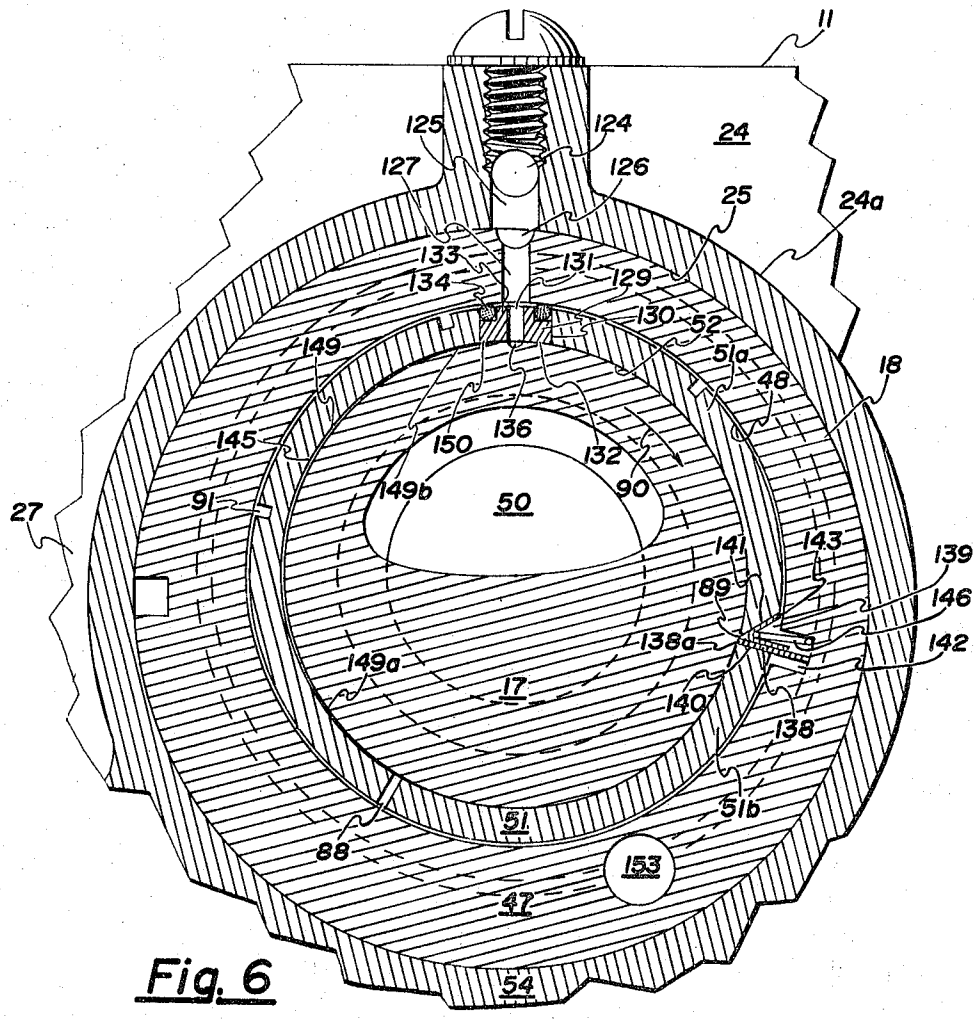



Fig. 6

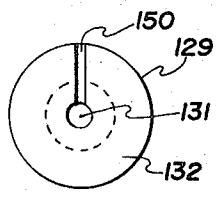



Fig. 20

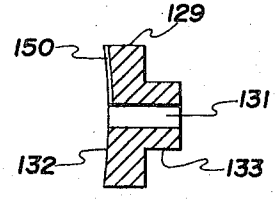
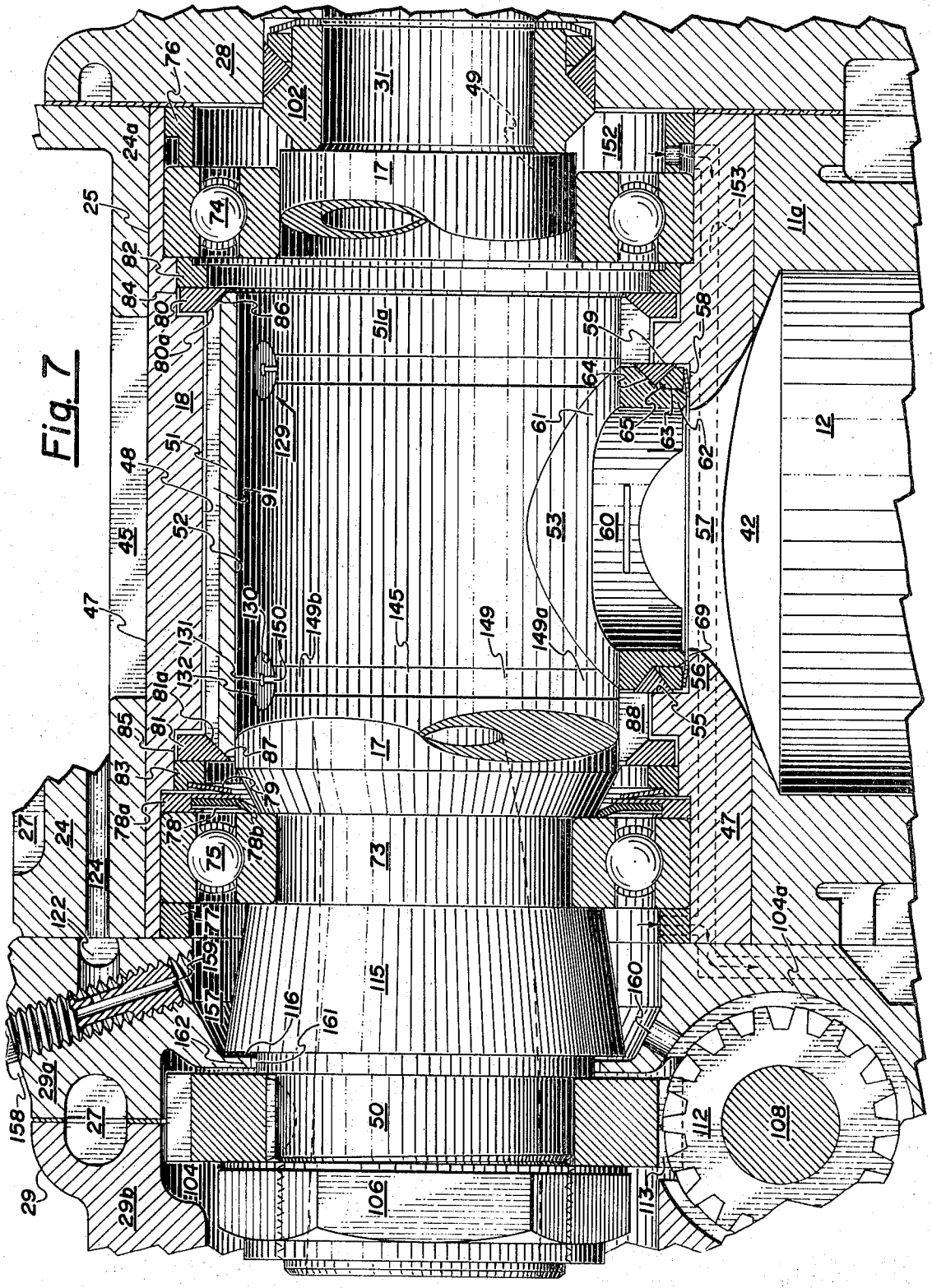



Fig. 21

Fig. 7


76
28
102
31
49
24a
25
74
17
152
153
110
82
84
80
80a
86
51a
59
58
64
18
61
65
63
62
12
51
48
129
91
52
60
53
57
42
45
47
130
150
149b
145
149
149a
69
56
131
132
81
81a
85
87
88
55
17
83
79
78
78a
78b
27
24
75
73
47
104a
122
124
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29b
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106
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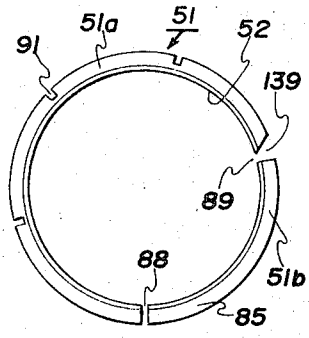



Fig. 13

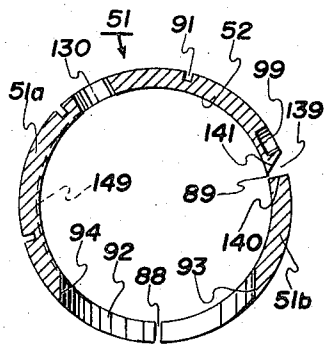



Fig. 14

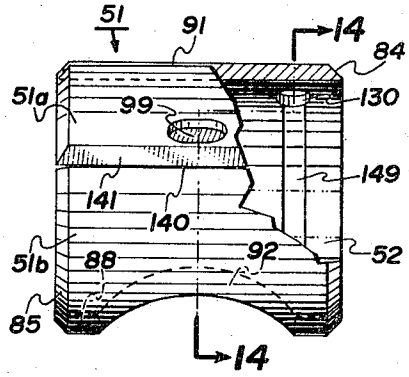



Fig. 12

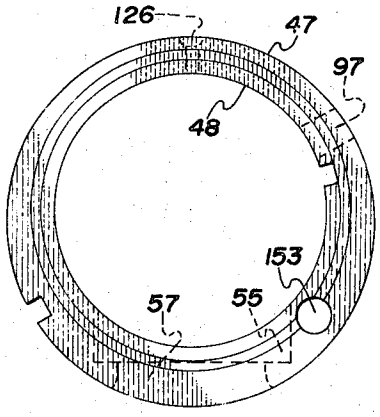



Fig. 11

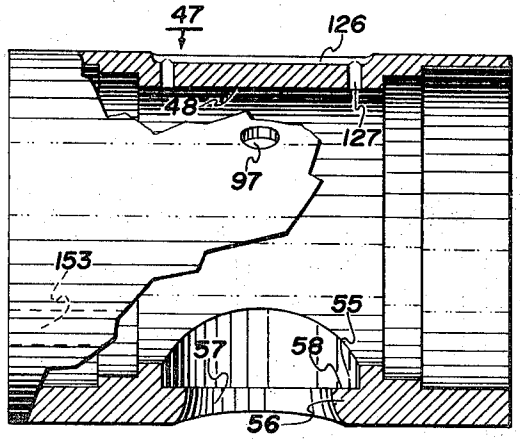



Fig. 10

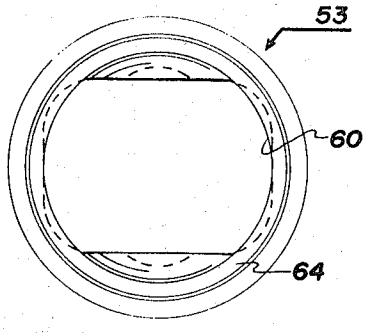



Fig. 17

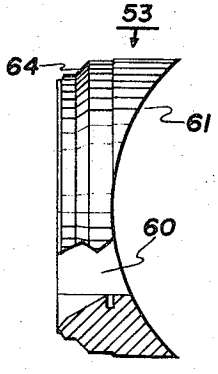



Fig. 16

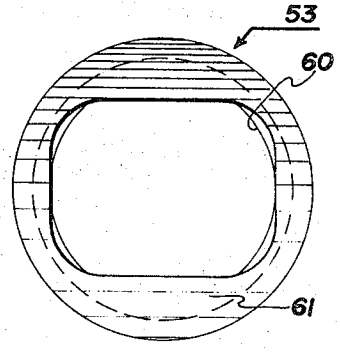



Fig. 15

# ROTARY VALVE INTERNAL COMBUSTION ENGINE

## BRIEF DESCRIPTION OF THE INVENTION

This invention relates to internal combustion engines and provides a novel form of rotary-valve internal combustion engine.

An object of the invention is to provide a novel rotary-valve internal combustion engine in which adequate, but not excessive, lubrication for the rotary valve or valves is achieved under all operating conditions of the engine.

Another object is to provide a novel rotary-valve internal combustion engine in which the feeding of lubricant to the valve or valves by a lubricant supply means is controlled during low-throttle and closed-throttle operation of the engine in a positive and precise manner by gas pressure supply means associated with the valve or valves so as to modify the feeding action of the lubricant supply means.

It is also an object of this invention to provide such a novel rotary-valve engine in which the supply of lubricant to the valve or valves is further controlled by a lubricant-metering valve device automatically responsive to varying load conditions of the engine.

A further object is to provide such a novel rotary-valve engine in which sleeve means in the valve bore is self-adjusting with respect to the running fit of the rotary valve therewith so that the valve functions in a highly efficient manner with a maintained low operating temperature and with minimum friction and wear at all times.

Yet another object is to provide a novel rotary-valve internal combustion engine in which dissipation of heat from high-heat areas and components is very effectively accomplished so that distortion or warping, which would tend to cause wear, binding or leakage, is prevented or kept to a minimum amount.

Still another object is to provide a novel rotary-valve engine in which the valve and certain components associated therewith comprise a preformed valve unit assembly located in an opening of the engine body and which is insertable and removable as such an assembly unit.

Additionally, this invention provides a novel rotary-valve internal combustion engine having multiple power cylinders and suitably driven rotary valves associated therewith and in which all of the above-indicated features and advantages are achieved, as well as the use of liquid coolant and an in-line relationship for the power cylinders.

Other objects, novel characteristics and advantages of this invention will be apparent in the following detailed description and in the accompanying drawings forming a part of this specification and in which

FIG. **1** is a top plan view, with portions in section, showing the novel rotary-valve engine of this invention;

FIG. **2** is a side elevation of the engine from the intake side thereof and with portions broken away;

FIG. **3** is a side elevation from the exhaust side of the engine and with portions broken away;

FIG. **4** is a transverse vertical section taken through the engine approximately as indicated by section line **4—4** of FIGS. **1** and **3**;

FIG. **5** is a partial vertical section, on a larger scale, taken longitudinally of the engine and transversely of one of the rotary valves, as indicated by the irregular section line **5—5** of FIG. **4**;



FIG. **6** is another such partial vertical section taken transversely of one of the rotary valves, but at a location offset from the longitudinal vertical mid-plane of the engine as indicated by the irregular section line **6—6** of FIG. **4**;

FIG. **7** is a partial sectional view taken through one of the rotary valves longitudinally thereof and as indicated by the section line **7—7** of FIG. **5**;

FIG. **8** is a partial transverse vertical section taken through a lubricant metering device as indicated by section line **8—8** of FIGS. **1** and **3**;

FIG. **9** is a fragmentary sectional view corresponding with a portion of FIG. **5** but on a still larger scale and further illustrating the packing means associated with the sealing shoe of one of the rotary valves;

FIG. **10** is a side elevation, with portions in section, of the casing member of one of the rotary valve units and showing such casing member in a detached relation;

FIG. **11** is an end view of the valve casing member of FIG. **10**;

FIG. **12** is a side elevation, with portions in section, of the sleeve of one of the rotary valve units and showing such sleeve in a detached relation;

FIG. **13** is an end view of the sleeve of FIG. **12**;

FIG. **14** is a transverse section through such sleeve taken on the irregular section line **14—14** of FIG. **12**;

FIG. **15** is a top plan view of the sealing shoe of one of the rotary valve units and showing such show in a detached relation;

FIG. **16** is a side elevation of the sealing shoe with portions thereof in section;

FIG. **17** is a bottom plan view of the sealing shoe;

FIGS. **18** and **19** are side and end views respectively of a sleeve abutment insert of one of the valve assembly units and showing such abutment insert in a detached relation;

FIGS. **20** and **21** are bottom plan and transverse sectional views respectively of a lubricant feeding insert member for the sleeve of one of the valve assembly units and showing such feeder insert in a detached relation;

FIG. **22** is a detached elevational view of a lubricant-feeding jet member of the engine;

FIG. **23** is a perspective view in detached relation of a lubricant scraper member of one of the valve assembly units; and

FIG. **24** is an expanded perspective view showing a lubricant check valve member and associated valve spring of one of the valve assembly units.

## DETAILED DESCRIPTION OF THE DRAWING

As a practical and preferred embodiment of this invention, the accompanying drawings show an internal combustion engine **10** of the rotary-valve type. The engine **10** comprises, in general, an engine body structure **11** having one or more cylinders **12**, in this case a plurality of such cylinders in an upright longitudinal in-line arrangement consisting of four cylinders **12***a*, **12***b*, **12***c* and **12***d*, and pistons **13** operable in such cylinders and connected with a power output shaft **14** by connecting rods **15**.

The pistons **13** are here shown as being reciprocating pistons, and the power output shaft **14** is shown as being a crank-shaft having a power take-off pulley **16**

mounted thereon for auxiliary power supply purposes as is explained hereinafter. The engine **10** also comprises, as an important part thereof, rotary valves **17** (hereinafter at times referred to as valve members) controlling intake and exhaust communication with the respective cylinders and which valve members are embodied in preformed valve assembly units **18** to be further described hereinafter.

The engine body structure **11** is of a suitable construction and is here shown as comprising a main body section **11***a* in the form of a cylinder block containing the bores of the cylinders **12**, a lower body section **21** containing the upper portion of a crankcase chamber **22**, and a splash pan **23** connected with the lower body section **21** for completing the crankcase chamber. The upper portion of the body structure **11** is a valve casing section **24** which is connected with the main body section **11***a*, in this case formed integral therewith, and contains transversely extending valve unit receiving bores **25** associated with the respective cylinders **12**.

The main body section **11***a* is provided with coolant space or passages **27** to accommodate cooling fluid, preferably water, and which coolant space is closed on the sides and top of the engine by cover members **28**, 29 and **30** suitably attached to such main body section. The cover member **28** is located on the intake side of the engine and has a longitudinal row of intake openings **31** therein. The cover member **29** is located on the exhaust side of the engine and is provided with a longitudinal row of exhaust openings **32**. For a purpose which will appear hereinafter, the cover member **29** is formed by two connected cover sections **29***a* and **29***b*.

The engine **10** is equipped with the usual auxiliary devices which include a craking motor **35**, a distributor **36**, and a carburetor **37**. The engine **10** also includes a conventional breather pipe **38** communicating with the chamber **22** of the crankcase, and an intake manifold **39** for supplying intake mixture from the carburetor **37** to the intake openings **31**. Additionally, the engine **10** is equipped with other conventional components (not shown) including a lubricant supply pump, a coolant impeller or water pump, and an exhaust manifold on the exhaust side of the engine and located to receive exhaust gases from the openings **32**.

The upper end portions of the cylinders **12** provide combustion chambers **42** in which the intake fluid is compressed by the pistons **13** and ignited by suitably located spark plugs **43**. The combustion chambers **42** are connected with the associated valve unit receiving bores **25** by relatively short connecting passages **44** which open into the receiving bores radially thereof. The valve casing section **24** of the main body member **11***a* includes wall portions **24***a* which extend in a curved relation around the receiving bores **25** (see FIG. **5**) and are positioned so that heat will be readily conducted therethrough from the valve units **18** to the coolant located in the coolant space **27**. The wall portions **24***a* preferably have openings **45** therein (see FIG. **5**) to further promote such transfer of heat from the valve units **18** to the coolant. Surface portions on the exterior of the valve units **18** are exposed through the openings **45** to the coolant for direct contact thereby.

The valve units **18** for the respective cylinders **12** are all of the same construction and only one of these valve units need be described in detail. As shown in the drawings, the valve unit **18** comprises a valve casing **47** containg a valve bore **48**, and one of the above-mentioned rotary valve members **17** operable in such valve bore and having intake and exhaust passages **49** and **50** for the intake and exhaust fluids. The intake and exhaust passages **49** and **50** extend axially of the valve member **17** and include radially disposed intake and exhaust ports **49***a* and **50***a* on the intermediate portion of the valve member. The valve unit **18** also comprises a sleeve **51** coaxially disposed in the casing **47** and in which the valve member **17** is rotatably operable in running contact with the inner wall **52** of such sleeve. Additionally, the valve unit **18** comprises a sealing shoe **53** in engagement with the valve member **17** peripherally thereof and which forms a seal extending around the connecting passage to the cylinder **12**.

The valve casing **47** is a substantially rigid tubular member having the valve bore **48** eccentrically located therein so that the casing member has a relatively thick wall portion **54** on the side thereof adjacent the cylinder **12**. This thick wall portion **54** accommodates the sealing show **53** and, for this purpose, the casing **47** has a radially disposed recess **55** in the intermediate portion thereof and in which the show is recieved. The portion of the casing adjacent the recess **55** includes an annular wall portion **56** extending around a radial opening **57** and providing a seat **58** facing away from the adjacent cylinder. The opening **57** is in continuous communication with the connecting passage **44** for the cylinder.

The sealing show **53** is a ring-shaped member which is shown in FIGS. **15**, **16** and **17** as having a control port **60** extending therethrough and a concave bearing surface **61** on one side thereof and surrounding the control port. The concave bearing surface **61** is in running contact and sealing engagement with the peripheral surface of the valve member **17**, as shown in FIGS. **4** and **5**, so that rotation of the latter brings the radially disposed intake and exhaust ports **49***a* and **50***a* thereof into communication in succession with the port **60** of the sealing shoe. The sealing shoe **53** has a relatively reduced annular lower end portion **62** adjacent the seat **58** and spaced from the annular side wall **59** of the valve casing recess **55** to provide therebetween an annular packing chamber **63**.

The bottom wall of the packing chamber **63** is formed by the seat **58** and the upper wall of the packing chamber is formed by an annular beveled surface **64** formed on the sealing shoe **53**. A packing **65** in the form of a sealing and heat-transfer packing means is located in the packing chamber **63**. The packing **65** is here shown (see FIG. **9**) as comprising cooperating upper and lower sealing and heat-transfer metal rings **66** and **67** and an associated spring ring **68**. The spring ring **68** is preferably annularly continuous, but the rings **66** and **67** are expansible and contractible as by being appropriately split at one point of the circumference thereof. The lower end of the packing chamber **63** is in restricted communication with the connecting passage to the cylinder **12** through the annular crevice **69**.

The upper sealing and heat-transfer ring **66** is of a triangular cross-sectional shape and is disposed with the sloping side **66***a* thereof in sealing and heat-transfer engagement with the beveled surface **64** of the shoe **53** and the base **66***b* in sealing and heat-transfer engagement with the surrounding thick wall portion **54** of the casing **47**. The engagement of the sloping side **66***a* with the beveled surface **64** is also a wedging engagement by which the ring **66** is expanded in the packing chamber

63 when the side 66*a* is forced against the beveled surface. The other sloping side 66*c* of the ring 66 faces toward the lower ring 67 for thrust engagement thereby.

The lower sealing and heat-transfer ring 67 is shown as being of a quadrangular cross-sectional shape except for a truncated portion thereon providing an inclined annular thrust surface 67*a* in wedging engagement with the sloping side 66*c* of the upper ring 66. A side 67*b* of the ring 67 is in sealing and heat-transfer engagement with the reduced portion 62 of the shoe 53, while the lower surface 67*c* is presented toward the seat 58 and engaged by the spring ring 68. The wedging engagement of the inclined side 67*a* with the sloping side 66*c* of the ring 66 causes the side 67*b* to be pressed against the reduced portion 62 of the shoe 53. Although a spring ring washer 68 is depicted, other loading methods such as a stainless steel wave washer have been successful and are in current use within particular engine configurations.

The sealing shoe 53 can be made of any suitable material but is preferably formed of metal which is a good bearing material and which also has a high co-efficient of heat conductivity, such as brass or bronze. The sealing and heat transfer rings 66 and 67 of the packing 65 are likewise made of a metal having a high coefficient of heat conductivity, such as brass or bronze, to further promote a rapid transfer of heat from the adjacent portions of the sealing show 53 to the valve casing 47.

The valve member 17 has coaxially disposed tubular end portions 72 and 73 (see FIG. 4) in which the intake and exhaust passages 49 and 50 are located. The intake and exhaust ports 49*a* and 50*a* of the valve member 17 are at the inner ends of the passages 49 and 50 and are radially disposed ports as mentioned above. The valve member 17 is rotatably supported in the casing 47 by a pair of antifriction bearings 74 and 75 extending around the tubular portions 72 and 73 and having their outer races seated in counterbores of the casing (see FIGS. 4 and 7). The antifriction bearings 74 and 75 are retained in the counterbores of the casing 47 by suitable retainer rings 76 and 77 which are pressed into the counterbores and are here shown as located between the outer races and the adjacent cover members 28 and 29 of the engine body 11.

Adjacent the antifriction bearing 75 a packing ring assembly 78 (see FIG. 7) is provided in the valve casing 47 for preventing or restricting the passage of lubricant through this bearing. The packing assembly 78 comprises a base ring 78*a* lying against the outer race of the bearing 75, and a flexible sealing ring 78*b* extending inwardly from the base ring and having its lip portion in engagement with the valve member 17.

The sleeve 51 of the valve unit 18 performs an important function in connection with the sealing and lubricating of the valve member 17 and the construction and mounting of this sleeve will be described next. The sleeve 51 is a flexible metal sleeve so as to be contractible into close sealing engagement, running contact and heat-transfer engagement with the periphery of the valve member 17. By reason of its flexible character and the manner in which it is supported between the valve member 17 and the wall of the casing 47, the sleeve 51 also has an expanding capability enabling the same to accommodate expansion and contraction of the valve member due to heating thereof. The expanding and contracting movements of the sleeve 51 are produced in the manner explained hereinafter and result in a proper positioning of the sleeve around the valve member 17 in correct running relation thereto and which positioning will be automatically adjustable for all operating conditions of the engine.

The sleeve 51 is supported on the valve member 17 in a floating relation thereto and with a small radial clearance between the sleeve and the wall of the valve bore 48. Axial positioning of the sleeve 51 is accomplished by a pair of floating sleeve-contracting rings 80 and 81 and a pair of abutment rings 82 and 83 associated therewith. The pairs of associated sleeve-contracting and abutment rings 80, 82 and 81, 83 are disposed in a pair of inner counterbores 84 and 85 of the valve casing 47 so that the rings 80, 82 are adjacent the bearing 74 and the rings 81, 83 are adjacent the packing ring assembly 78.

At the ends thereof the sleeve 51 is provided with external annular beveled surfaces 80*a* and 81*a* of the contracting rings 80 and 81 cooperate. The sleeve 51 is a split sleeve and is here shown as having two longitudinal splits 88 and 89 therein, and of which the split 88 is interrupted so that end portions thereof lie on axially opposite sides of the sealing shoe 53 as shown in FIGS. 5 and 7 and the split 89 is a full-length or uninterrupted split. The sleeve 51 is comprised of curved segments, in this case two such segments 51*a* and 51*b* extending arcuately between the splits 88 and 89.

The abutment ring 83 is engaged on the side thereof facing the bearing 75 by the spring ring 79 and is axially shiftable in the inner counterbore 85 by the reaction of this spring ring thereagainst so that the beveled annular surfaces 80*a* and 81*a* of the contracting rings 80 and 81 are maintained in wedging engagement with the beveled surfaces 86 and 87 of the sleeve 51 to continuously exert a contracting tendency thereon. All of the rings 80, 81, 82 and 83 are heat-transfer rings for conducting heat from the sleeve 51 to the casing 47, and accordingly, these rings are made of a material having good heat conductivity such as brass, bronze, aluminum, or graphite.

The contracting rings 80 and 81 have flat annular surfaces on the remote sides thereof which are slidable on, and have large-area heat-transfer contact with, the adjacent side surfaces of the abutment rings 82 and 83 during the radial floating movements of the contracting rings. The outer peripheral surfaces of the abutment rings 82 and 83 likewise have a large-area heat-transfer contact with the walls of the inner counterbores 84 and 85. These large-area contact surfaces and the good heat-conducting material of the rings thus provide for an efficient transfer of heat from the valve member 17 to the valve casing 47 through the sleeve 51 and the pairs of rings 80, 81 and 81, 83.

The automatic self-adjusting movement of the sleeve 51 is an expanding movement in opposition to the contracting force of the rings 80 and 81 and results, in part, from an unwrapping tendency imparted to the sleeve by the rotative action of the valve member 17 whose rotation is a clockwise rotation as indicated in FIGS. 5 and 6 by the directional arrow 90. The self-adjusting characteristic of the sleeve 51 also results in part from an inherent flexibility by reason of the sleeve being a longitudinally-split sleeve as described above, and by reason of the presence of radial slots 91 in the outer periphery thereof which extend axially for the full length of the sleeve as shown in FIG. 7. The self-adjusting action of the sleeve 51 also results from the expansion

and distortion of the valve member **17** due to heating thereof, as well as from heating of the sleeve itself.

As to the form of the sleeve **51** as shown in the drawings (see FIG. **6**), it is pointed out that the segment **51***a* thereof is a relatively long segment extending circumferentially around the valve member **17** for approximately three-fourths of the circumference thereof, and the segment **51***b* is a relatively short segment extending for approximately one-fourth of the circumference of the valve member. The sleeve **51** is provided with a radial opening **92** therein which is aligned substantially with the recess **55** of the valve casing **47** and in which the concave end of the sealing shoe **53** is received.

An alternate configuration for this sleeve **51** is to produce it in one piece containing longitudinal grooves. Thus, the split sleeve segment, **51***a* and **51***b*, may be either incorporated into a single split piece, where the scraper and sleeve locating pins are omitted, or used as separate segments with scraper and sleeve locating pins as described within this disclosure.

In connection with the self-adjusting characteristic of the sleeve **51** it is pointed out that the clockwise rotation of the valve member **17** produces a frictional drag on the inner surface of the sleeve by which the above-mentioned unwrapping tendency is produced. Because of the self-expanding action of the sleeve **51** produced by the unwrapping tendency thereof, the frictional drag on the valve member **17** is automatically kept at a minimum value. The frictional drag produced by the valve member **17** tends to carry the segment **51***a* in the same rotative direction but actual rotation of the segment is limited to a very small amount of circumferential shifting by the seating engagement of the edge wall portion **93** thereof against the adjacent side of the sealing shoe **53** as shown in FIG. **5**. A similar circumferential shifting of the segment **51***a* permits the opposite edge wall portion **94** to shift away from the other side of the sealing shoe **53**. Where a single piece split sleeve is used rather than multiple separate segments, the locating inserts such as **96** and the matching radial openings such as **97** (see FIGS. **5**, **19** and **20**) would be eliminated. The whole sleeve is kept from rotation by the sealing shoe **53**.

By reason of the construction and mounting for the sleeve **51**, as explained above, it will accordingly be seen that the sleeve will always be maintained in close contact with the periphery of the valve member **17** but binding or seizing of the valve member in the sleeve will be prevented because the self-adjusting tendency of the sleeve will always act to automatically relieve or prevent any such binding or seizing. As heating of the sleeve **51** occurs and the temperature thereof increases progressively with increasing loads and operating speeds of the engine, the self-adjusting tendency of the sleeve due to such heating will likewise relieve or prevent any likelihood of binding or seizing of the valve member **17**.

Where two or more separate segments are used such as **51***a* and **51***b* depicted in FIG. **5**, rather than single piece sleeve construction, some form of locating inserts such as **96** and **97** would be required. With a single, rather than multiple segment sleeve, the whole sleeve would be kept from rotation by the sealing shoe **53**. For the multiple separate segment configuration, the circumferential positioning of the sleeve, **51**, in the valve bore, **48**, can be varied or adjusted by means of an abutment insert **96** provided in a radial opening **97** of the valve casing **47**. The abutment insert **96** has a cylindrical body portion received in the radial opening **97** and a noncircular end portion, in this case a substantially square end portion **98** which projects into a suitably shaped recess **99** of the sleeve **51**. The square end portion **98** is formed on the insert **96** in an eccentric relation to the axis of this member so that each of the four sides of the square portion will, in succession, provide differently located stop surfaces for engagement by the edge portion **99***a* of the sleeve when the insert is rotated to different adjustment positions.

The abutment insert **96** is also provided with a threaded recess **100** extending axially thereinto from the outer end thereof. By engaging a suitable threaded tool in the recess **100** the abutment insert **96** can be withdrawn from the opening **97** and rotated sufficiently to locate any desired one of the side faces of the square portion **98** in the proper location for engagement by the edge portion **99***a* of the sleeve. By thus adjustably positioning the abutment insert **96** in the valve casing **47**, the circumferential location of the sleeve **51** in the valve bore **48** can be established as desired and thus allows suitable machining tolerance.

The valve unit **18** was previously referred to herein as being a preformed valve assembly unit. Such a valve unit is associated with each of the cylinders **12** and is removably received in the associated valve bore **25**. Each such valve assembly unit **18** comprises the valve casing **47**, the antifriction bearings **74** and **75**, the valve member **17** rotatably supported by such bearings, and the split sleeve **51** surrounding the valve member. Additionally, the valve unit **18** includes the packing ring assembly **78** and a set of the various rings **76**, **77**, **80**, 81 and **82**, **83**. These components can be assembled as a bench operation so that the valve unit **18** can be inserted or removed as such in the receiving bore **25**. The valve unit **18** is retained in the receiving bore **25** partly by a press fit therein and partly by the cover members **28** and **29** of the engine body **11**.

When the valve unit **18** is thus assembled in the receiving bore **25** a suitable sealing ring **102**, disposed in a recess **103** of the cover member **28**, cooperates with the adjacent tubular intake portion **72** of the valve member **17**. The tubular exhaust portion **73** of the valve member **17** projects into a gear chamber **104**, provided in the cover member **29** between the connected sections **29***a* and **29***b* thereof, and cooperates with a suitable sealing ring **105** disposed in a recess **106** of such cover member.

The valve members **17** of the engine **10** are suitably driven in a timed relation to the operation of the pistons **13** in the cylinders **12** and, in this case, the valve actuating shaft **108** is provided and extends longitudinally of the engine on the exhaust side thereof. The valve actuating shaft **108** is rotatably mounted in the engine body **11** by suitable bearings formed, in part, by bearing elements provided on the cover section **29***a* and, in part, by bearing caps **107**. The shaft **108** extends in a direction transverse to the tubular exhaust portions **73** of the valve members **17** at a location below the latter. The valve actuating shaft **108** is suitably driven from the crankshaft **14**, as by means of a toothed belt **109** extending around the crankshaft pulley **16** and around a pulley **110** mounted on a projecting end portion **108***a* of the valve shaft.

The valve members **17** are connected with the valve actuating shaft **108** as by pairs of cooperating spiral-

tooth gears 112 and 113 of which the gears 112 are the driving gears and are secured on such shaft at longitudinally spaced points therealong. The gears 113 are secured on the tubular exhaust portions 73 of the valve members 17 and are retained thereon by clamping nuts 114. The gears 113 are spaced outwardly along the exhaust portions 73 from the adjacent bearings 75 by tapered tubular spacers 115 interposed between these gears and the inner races of such bearings. The spacers 115 are disposed with their large ends presented toward the gears 113 and such large ends are provided with annular grooves 116 for a purpose to be explained hereinafter.

The rotation of the valve members 17 by the shaft 108 brings the radial intake and exhaust ports 49*a* and 50*a* thereof into communication in succession with the control ports 60 of the sealing shoes 53, to thereby connect the intake and exhaust passages 49 and 50 with the combustion chambers 42 of the cylinders 12 in sequence to achieve, in this case, a four-stroke-cycle operation of the engine 10.

Proper lubrication of the valve members 17 and their support bearings 74, 75, as well as the driving means for the valve members, is very important to the successful operation of the engine 10 and is accomplished by novel lubricating means which will be described next with reference to one only of the valve members. Lubricant for the valve member 17 is supplied under pressure from a suitable source of lubricant supply such as the above-mentioned oil pump located in the crank chamber 22. The lubricant under pressure is supplied by the pump through a suitable conduit 118 which, as shown in FIGS. 1, 3 and 8, extends to a lubricant-metering valve device 119 mounted on the top portion of the engine. The quantity of lubricant supplied to the valve units 18 is metered by the lubricant-metering valve device 119, in a manner to be presently explained, and flows therefrom through delivery and connecting passages 120 and 121 into a main longitudinal supply passage 122 of the engine body 11. The supply passage 122 is here shown as formed in the cover section 29*a*.

Transversely extending lubricant distributing passages 124, individual to the valve units 18, are formed in the upper portion of the main body section 11*a* and extend along the receiving bores 25 for a portion of the length of the latter as branch passages leading from the main longitudinal supply passage 122. At the inner end thereof, each of the distributing passages 124 is connected with a port 125 which opens radially through the wall of the associated receiving bore 25 and communicates with a lubricant supply groove 126, the latter being formed in the outer periphery of the valve casing 47 and extending axially along the intermediate portion thereof. The supply groove 126 communicates adjacent its ends with axially spaced radial supply ports 127 formed in the valve casing 47 and opening through the inner wall of the valve bore 48. The supply ports 127 thus make supplies of lubricant under pressure available for feeding to each of the rotary valve members 17 at axially spaced points thereof.

The feeding of the lubricant from the supply ports 127 to the periphery of the valve member 17 is accomplished by lubricant-feeding orifice members 129 which are here shown in the form of button-like inserts mounted inaxially spaced radial openings 130 of the sleeve 51. The feed members 129 are provided with radially disposed feed orifices 131, of appropriate cross-sectional area, which receive oil under pressure from the supply ports 127 and feed the same to the outer periphery of the valve member 17.

As best seen in FIGS. 6, 7, 20 and 21, each of the feed members 129 is provided with a concave bearing surface 132 with which the outer periphery of the valve member 17 is in running engagement. The feed member 129 is provided on the opposite or outer side thereof with a reduced stem portion 133 through which the feed orifice 131 also extends. A flexible packing ring 134, located in surrounding relation to the stem portion 133, is in sealing engagement with the body portion of the feed member and with the inner wall of the valve casing 47 so as to confine the lubricant to the supply port 127 and the feed orifice 131.

The amount of lubricant supplied to the valve member 17 is a controlled amount determined largely by the volumetric capacity of lubricant pick-up pockets 136 provided in the periphery of the valve member at axially spaced points located so as to come into registration with the feed orifices 131 during the rotation of the valve member. Since the lubricant in the feed orifices 131 is maintained under pressure, the pick-up pockets 136 will be filled with pressurized lubricant during each passage of these pockets across the feed orifices. As the pick-up pockets 136 move in a clockwise direction away from the feed orifices 131, the lubricant contained in the pockets will flow therefrom and spread out as a film over the adjacent surface portions of the outer and inner peripheries of the valve member 17 and the sleeve 51.

An accumulation of excess lubricant on the adjacent surfaces of the valve member 17 and sleeve 51 is prevented by the provision of a scraper 138 at a point spaced from the feed orifices 136 and which applies a scraping action to the valve member for spreading the lubricant thereon and for removing excess lubricant therefrom. The scraper 138 is located in a radially-edgewise disposed relation to the valve member 17 and is here shown as being located in a valve chamber 139 provided between the adjacent edges 140 and 141 of the segments 51*b* and 51*a* of the sleeve 51. The valve chamber 139 is formed in part by the split 89 of the sleeve 51 and in part by an axial slot 142 formed in the valve casing 47 and opening in a radially inward direction through the wall of the valve bore 48.

The scraper 138 is shown in FIGS. 6 and 23 as being in the form of a flat blade having a longitudinally continuous straight inner edge 138*a* which engages the periphery of the valve member 17 and whose outer edge portion is received in the slot 142. The scraper 138 is yieldingly pressed against the valve member 17 by spring means which is here shown in the form of flexible arm portions 138*b* on the outer edge of the scraper adjacent the ends thereof. The spring arms 138*b* can, as shown in FIG. 23, be formed as deflected integral portions of the scraper blade.

The sides of the split 89 of the sleeve 51 are defined by the opposed edge walls 140 and 141 of the segments 51*b* and 51*a*, the wall 140 being a flat radial wall and the wall 141 being a beveled wall. The scraper blade 138 lies adjacent the flat radial edge wall 140 of the segment 51*b* and is spaced from the beveled wall 141 by the intervening valve chamber 139 into which the scraped-off excess lubricant is received by flowing past

a check valve member **143** located in this valve chamber.

The check valve member **143** is shown in FIGS **5, 6,** and **24** as being a hollow valve member of a V-shaped or triangular cross-section and having flat blade portions **143***a* and **143***b* extending in an outwardly diverging relation away from a longitudinal apex **144.** The check valve member **143** is disposed in the valve chamber **139** so that the blade portion **143***a* lies against the adjacent flat surface of the scraper blade **138** and the blade portion **143***b* lies against the beveled edge wall **141** of the segment **51.** The check valve member **143** is thus disposed in the valve chamber **139** so that inward radial shifting thereof causes the same to be wedged between the scraper blade **138** and the beveled edge **141** of the segment **51***a* and which wedging engagement is the closed or seated position of this valve member. When the check valve member is in its seated position the apex **144** is presented toward, but spaced from, the outer surface of the valve member **17.**

The check valve member **143** is urged toward a normally closed position in such seating engagement with the beveled edge **141** by suitable spring means which is here shown in the form of a wire spring **146** having an outwardly bowed intermediate portion **147** received in the slot **142** of the valve casing **47.** The spring **146** has straight end portions **148** received in the rear recess of the check valve member **143** and pressing against this valve member adjacent the ends thereof.

When excess lubricant is scraped from the valve member **17** by the blade **138** it accumulates in front of the blade and adjacent the check valve member **143.** A resulting pressure buildup in the accumulated excess lubricant causes an outward opening movement of the check valve member **143,** in opposition to the spring **146,** thereby permitting the excess lubricant to escape into the valve chamber **139** and the slot **142** from which it is suitably returned to the crankcase chamber **22** of the engine.

When the engine **10** is operating under load, the lubricant in the supply ports **127** and in the feed orifices **131** will be at an appreciable pressure value and, when a decrease occurs in the engine load or the throttle is suddenly closed for any reason, the lubricant-metering valve device **119** will automatically decrease or stop the supply of lubricant to the ports **127.** However, since lubricant is already present in the supply ports **127** and feed orifices **131** at the time that the valve device **119** reduces or stops the lubricant supply, there will be a tendency for a continued feeding of lubricant by the orifices and a resulting over-lubrication of the valve member **17** for the reduced-load or closed-throttle condition of the engine. To prevent such over-lubrication of the valve member **17** under these conditions and the undesirable resulting effects of a smoky exhaust and carbon deposits, a second lubricant control means is provided for automatically limiting the volume of the lubricant feed from the orifices **131** during the changed operating condition. This second lubricant control means comprises a gas pressure supply means **145** (see FIGS **6** and **7**) which will be described next.

The gas-pressure-responsive lubricant control means **145** makes use of the pick-up pockets **136** in conjunction with eccentric groove pump means comprising grooves **149** formed in the inner periphery of the sleeve **51** and extending circumferentially of the segment **51***a* in alignment with the feed orifices **131.** The eccentric grooves **149** constitute pump chambers for supplying gas under pressure directly to the feed orifices **131** in a contra-flow direction to the normal lubricant feed, and also to the pick-up pockets **136** for transfer to such feed orifices.

The gas pressure thus supplied to the feed orifices **131** during the reduced-load or sudden closed-throttle operation of the engine moves along the orifices toward the supply ports **127,** that is, in a contra-flow direction to the normal flow-delivery direction of the lubricant. This backward flow of gas pressure into the feed orifices **131** effectively stops the feeding of lubricant therefrom during the time that the reduced-load or closed-throttle condition prevails but, as soon as engine load again increases, the normal feeding of lubricant to the pockets **136** by the orifices will be resumed.

The eccentric grooves **149** are here shown (see FIG. **6**) as extending along the interior of the segment **51***a* between the openings **130** thereof and the edge portions lying adjacent the split **88.** The grooves **149** each provides a pump chamber of crescent-like form and which is of maximum depth along the intermediate portion and of minimum depth at or adjacent the ends thereof. The end portion **149***a* of the groove is an intake portion lying adjacent to and communicating with the split **88** and the end portion **149***b* is a discharge portion communicating with the feed orifice **131,** preferably through a shollow narrow transfer groove **150** (see FIGS. **7, 20** and **21**) formed in the concave surface **132** of the feed member **129.** As shown in FIG. **7** of the drawings, the locations of the eccentric grooves **149** axially of the sleeve **51** positions the intake ends **149***a* of these grooves in a communicating relation with the split **88** and with the clearance space adjacent the edge **94** of the sleeve.

During the rotation of the valve member **17** the pick-up pocket **136,** after discharging its lubricant charge, moves past the split **88** in the sleeve **51** at which time air is permitted to enter the then-empty or partially-empty pick-up pocket. The rotation of the valve member **17** also causes a pressure build-up of air in the eccentric groove **149** by a pumping action resulting from the frictional drag between the surface of the rotating valve member and the air present in the eccentric groove. The frictional drag between the air contained in the groove **149** and the valve member **17** causes such air to be pressurized in the discharge portion **149***b* of the groove with the result that the pressurized air flows in restricted quantities through the connecting groove **150** into the feed orifice **131.**

The clockwise rotation of the valve member **17** which advances the pick-up pocket **136** along the segment **51***a* from the location of the split **88** toward the feed member **129** causes such pocket to travel along the eccentric groove **149** in open communication therewith. The air which is pressurized in the groove **149** by the above-described frictional-drag pumping action causes a quantity of such pressurized air to fill the pick-up pocket **136** and to be carried by the latter to a point beneath the feed orifice **131,** whereupon the pressurized air in the pick-up pocket is descharged into the feed orifice in a contra-flow direction to the lubricant delivery flow to further restrict and control the delivery of lubricant during the reduced-load or closed-throttle operation of the engine.

The pumping action described above for the eccentric groove **149** and the transfer action of the associ-

ated pick-up pocket **136**, in supplying air under pressure to the feed orifice **131**, also takes place during high-load or open-throttle operating conditions of the engine, but the pressure of the lubricant in the supply port **127** and in the feed orifice **131** during either of these operating conditions is substantially higher than the pressure of the pumped air and will sufficiently overcome the contra-flow effect of the latter to result in an adequate supply of lubricant to the valve member **17** during such conditions.

If excess oil is present on the rotor (the oil forming a groove seal) the reverse pumping is enhanced whereas if dry of oil the reverse pumping stops and more oil will enter the area insuring balanced lubricaton during idle or no-load operation.

Although the functioning of the eccentric groove **149** as a pumping means and the transfer action of the pick-up pocket **136** have been described above with respect to air as the pressurized control medium being supplied to the feed orifice **131**, the pressurized medium thus supplied may also be combustion gas, or a mixture of combustion gas and air, which enters the eccentric groove. The combustion gas entering the groove **149** is a leakage portion of the combustion gas which finds its way between adjacent surface portions of the components of the valve unit **18** or past the packing means **65** thereof.

The antifriction bearing **74** is lubricated by a portion of the lubricant supply delivered to the valve member **17** which escapes along such valve member axially thereof and passes through the bearing into an annular lubricant collecting space **152** (see FIG. 4). The collecting space **152** is suitably connected with the crankcase chamber **22** for the return of the collected lubricant to the latter. As shown in FIG. 7 the return path for this collected lubricant can be provided by an axial passage **153** in the valve casing **47** and a descending passage **154** in the engine body **11**, the latter passage leading to the crankcase chamber **22**. The lubricant in the collecting space **152** flows therefrom into the passage **153** through a radial port **155** and annular groove **156** of the bearing retaining ring **76**.

A portion of the lubricant supplied to the main longitudinal supply passage **122** is used to cool the exhaust portion **73** of the valve member **17** and to lubricate the adjacent antifriction bearing **75** and the associated pair of gears **112** and **113**. For this purpose an annular lubricant chamber **157** is provided adjacent the outer end of the bearing **75** in surrounding relation to the spacer **115**. Lubricant from the longitudinal supply passage **122** is discharged into the lubricant chamber **157** through a nozzle member **158**, in this case, in the form of a hollow screw threaded into the cover member **29** so that the passage **159** of the screw serves as a jet passage for directing lubricant into the chamber **157** and against the rotating spacer **115**. The area of the jet passage **159** also serves to determine the lubricant pressure in the supply passage **122**.

The spacer **115** is made of a metal having a high coefficient of heat conductivity and lies in direct contact with the tubular exhaust portion **73** of the valve member **17**. The lubricant supplied to the chamber **157** is therefore in direct heat-exchange relation to the exhaust portion **73** for absorbing heat therefrom. The spacer **115** is also in heat-removing contact with the inner race of the bearing **75** for cooling the latter.

The lubricant in the chamber **157** is also directly available to the bearing **75** for lubricating the same. Lubricant entering this bearing is prevented from flowing in an inward axial direction along the valve member **17** by the above-described packing ring assembly **78** located on the inner side of this bearing.

A portion of the lubricant supplied to the chamber **157** is discharged directly into the gear chamber **104** through a short passage **160** of the cover member **29***a* for lubricating the gears **112** and **113**. The feeding of lubricant to the gear chamber **104** also takes place through a labyrinth-type of resticted annular feed passage **161** formed between adjacent portions of the spacer **115** and a surround annular lip **162** carried by the cover member **29***a*. The lip **162** projects into the annular groove **116** which is located immediately adjacent the gear **113** and, as mentioned above, is provided in the base portion of the spacer **115**. During the rotation of the spacer **115** with the exhaust portion **73** of the valve member **17**, lubricant will travel along the spacer to the large-diameter end thereof and will thus be caused to flow through the restricted annular feed passage **161** into the gear chamber **104** and onto the gear **113**.

The lower portion of the gear chamber **104** provides a depending pocket **104***a* in which the driving gear **112** is located. The pocket **104"** provides a lubricant collecting chamber in which a pool of lubricant is retained after the engine **10** has been stopped and which serves as an initial supply of lubricant for the gears **112** and **113** when the engine is again started up. This pool of lubricant in the pocket **104***a* assures adequate lubrication for gears **112** and **113** until the engine is loaded sufficiently for the lubricant-metering valve device **119** to become effective in supplying lubricant to the main passage **122**.

Since the gear chamber **104** is supplied with lubricant directly through the passage **160**, the pocket **104***a* will always be maintained full of lubricant during running of the engine in a loaded condition so that the gears **112** and **113** will be adequately lubricated. The rotation of the gear **112** in the pocket **104***a* throws lubricant therefrom onto the gear **113** to thus lubricate the latter as well as to cause cooling of the exhaust portion **73** of the valve member **17**.

It was mentioned above that the lubricant supplied to the main longitudinal supply passage **122** is supplied thereto by the lubricant-metering valve device **119** and this device will be described next. The metering device **119** comprises a diaphragm housing **164** formed of connected sections **164***a* and **164***b* and attached to the top cover member **30** of the engine body **11** by suitable screws **165**, and a valve housing **166** formed as an integral part of the cover member **30** and depending therefrom into the coolant space **27**. The lubricant metering device **119** also comprises a diaphragm **167** located in a diaphragm chamber **168** of the houisng **164** and a valve body **169**, here shown in the form of a spool, received in a valve chamber **170** of the valve housing **166**.

Additionally, the lubricant feeding device **119** comprises a metering rod **171** connected with the diaphragm **167** and slidably movable in a passage **172** of the valve body **169** and provided with a groove of varying depth as a metering passage **173**. The groove **173** is longer than the axial length of the valve body passage **172**. The metering rod **171** is also provided below the

groove 173 with a beveled annular valve member 174 which is engageable with the lower end of the valve body 169 for completely closing the passage 172 of the latter.

The diaphragm chamber 168 is connected with the intake passage 31 of the engine by a connecting passage 175 so that the diaphragm 167 is subjected to intake vacuum on the upper side thereof. The chamber portion 168*a* beneath the diaphragm 167 is suitably vented to atmosphere. A compression spring 176 located in the diaphragm chamber 168 is effective on the diaphragm 167 in opposition to the intake vacuum and in a direction tending to cause a downward movement of the metering rod 171 for opening actuation of the metering orifice 173 and for cause opening movement of the valve member 174 away from the valve body 169.

The valve body 169 is provided with packing rings 175 and 176 at axially spaced points thereof which cooperate with the wall of the valve housing 166 so that the portion of the valve chamber 170 lying between these packings constitutes an inlet chamber 170*a* in the metering device 119 for receiving lubricant under pressures from the supply conduit 118 through a connecting passage 177. The valve body 169 is retained in the valve chamber 170 by the lower section 164*b* of the diaphragm housing 164 but with intervening grooves or space 178 therebetween connecting the discharge side of the metering orifice 173 with an annular delivery chamber 179. The delivery chamber 179 is connected with the main longitudinal supply passage 122 by the previously mentioned delivery and connecting passages 120 and 121.

The valve body 169 is provided in the lower end thereof with a cylinder 180 in which a damping piston 181, mounted on the metering rod 171, is reciprocably movable. The cylinder 180 provides a dashpot chamber to which lubricant is supplied from the inlet chamber 170*a* through one or more openings 182 of the valve body 169. The piston 181 operates with suitable clearance in the cylinder 180 so that the cylinder portions above and below the piston will be filled with lubricant and the movements of the piston in the cylinder will be resisted and damped for assisting in stabilizing the movements of the metering rod 171.

From the construction of the lubricant feeding device 119 as above described it will be recognized that the diaphragm 167, by reason of the action of the spring 176 thereon, imparts a downward actuating movement to the metering rod 171 in an opening direction for the metering orifice 173 and for the valve member 174 whenever intake vacuum of the engine is at a relatively low value, that is to say, whenever the engine is operating with a wide throttle opening. The open condition of the orifice 173 and the valve member 174 accordingly cause an increased amount of lubricant to be supplied to the main delivery passage 122 for feeding to the rotary valve 17, to the gears 12 and 13, and for cooling the exhaust portions 73 of the rotary valve members.

Conversely when the intake vacuum of the engine increases sufficiently to overcome the action of the spring 176, occurring during partial and closed throttle positions the diaphragm 167 will lift the metering rod 171 to close the metering orifice 173 and also cause closing of the valve member 174 whereby lubricant delivery to the main longitudinal supply passage 122 will be cut off. For different intermediate throttle positions the opening of the orifice 173 will be varied accordingly to regulate the amount of lubricant being delivered by the metering device 119 to the main supply passage 122.

It will accordingly be understood that the lubricant metering device 119 will automatically respond to operating conditions of the engine 10 for correspondingly varying the amount of lubrication being supplied to the rotary valves 17 and the associated movable components to suit the requirements of the engine. Since the lubricant supply for the rotary valves 17 and the associated movable components requiring lubrication is thus automatically controlled in accordance with the needs and operating conditions of the engine, the problems and harmful effects of over-lubrication and under-lubrication will be successfully avoided.

Since the valve housing portion 166 of the lubricant metering device 119 extends into the coolant space 27 of the upper portion of the engine body 11, so as to have direct heat-exchange contact with the coolant therein, additional advantages are achieved. One of these advantages is that whenever operating conditions of the engine are such that the temperature of the lubricant is relatively high, a cooling of the lubricant will be achieved by transfer of heat therefrom to the coolant in the space 27. This will assist in preventing under-lubrication and overheating of the valve members 17 and in preventing an unduly low viscosity of the lubricant due to heating thereof.

Another of these advantages is that, conversely, whenever the condition of operation of the engine is such that the temperature of the coolant is higher than the temperature of the lubricant, a transfer of heat to the latter will take place and result in an increase in the temperature and a decrease in the viscosity of the lubricant, which, renders the lubricant more suitable and effective for efficient lubrication of the valve members 17 and the associated moving components, particularly when the engine 10 is started up from a cold condition.

From the accompanying drawings and the foregoing detailed description it will now be readily understood that this invention provides a novel rotary-valve internal combustion engine in which various important constructional features and operating advantages hereinabove described are present or obtained and result in an engine having a high power output capability in relation to its size and weight and an engine which will operate in a satisfactory and efficient manner throughout a wide range of operating speeds and load conditions and during a long and useful life with a minimum amount of servicing on account of the occurrence of wear, replacement needs, carbon deposits or the like. Additonally, it will be understood that wherever servicing of the rotary valves of the engine becomes necessary, such work will be greatly facilitated by reason of the removable character of the valve assembly units which permits quick and easy replacement of the removed units by new or reconditioned units.

Although the rotary-valve internal combustion engine of this invention has been illustrated and described herein to a somewhat detailed extent, it will be understood, of course, that the invention is not to be regarded as being limited correspondingly in scope but includes all changes and modifications coming within the terms of the claims hereof.

What is claimed is:

1. In a internal combustion engine:

an engine body having a cylinder and valve casing means providing a valve bore extending transversely of the cylinder and connected with one end of the latter;
a piston operable in said cylinder;
antifriction bearings mounted in said casing means and spaced apart axially thereof;
sleeve means disposed in said casing means and extending axially thereof between said bearings;
port means in the walls of said casing means and sleeve means and connected with said cylinder;
a rotary valve supported by said bearings for operation in said sleeve means and controlling the communication with said cylinder through said port means;
said sleeve means being flexible and having beveled end portions; and
contracting means engaging said end portions for contracting said sleeve means around said valve.

**2.** An internal combustion engine as defined in claim 1 wherein:
said sleeve means is of shorter length than the axial spacing of said bearings; and
wherein said contracting means comprises ring members having annular tapered portions in wedging engagement with said beveled portions, said ring members being disposed between portions of said bearings and the end portions of said sleeve means.

**3.** In an internal combustion engine:
an engine body having a cylinder providing a combustion chamber, a receiving bore adjacent said cylinder and a passage connecting the combustion chamber with said receiving bore;
a piston operable in said cylinder;
a substantially rigid tubular valve casing mounted in said receiving bore;
flexible sleeve means in said casing;
said casing and sleeve means having substantially aligned radial openings in communication with said passage, and said casing also having an annular seat surrounding the radial opening thereof;
a rotary valve having passage means therein;
antifriction bearings in said casing and supporting said valve for rotation in said sleeve means;
said sleeve means having beveled end portions;
contracting members having tapered portions in wedging engagement with said end portions for contracting said sleeve means around paid valve;
a sealing shoe having a concave surface slidably engaged by said valve, and a port connected with said passage and controlled by said valve;
said shoe being received in said radial openings and engaged with said annular seat;
the portion of said shoe engaged with said seat being a relatively reduced end portion defining with adjacent portions of said casing an annular packing recess extending around said port; and
packing ring means in said packing recess, said casing, valve, bearings, sleeve means, shoe and packing ring means comprising a preformed valve assembly unit disposed in said receiving bore and removable therefrom as such unit.

**4.** In an internal combustion engine:
an engine body having a cylinder and valve casing means containing a valve bore and a passage for combustion fluid connecting said valve bore with said cylinder;
a piston operable in said cylinder;
a rotary valve operable in said valve bore and controlling said passage;
supply passage means leading to said valve bore for supplying lubricant to the periphery of said valve;
said casing means having a substantially radially disposed slot extending along said valve bore and located in the periphery thereof;
lubricant scraper blade means in said slot and engaging said valve;
lubricant discharge passage means leading from said slot; and
check valve means in said slot alongside said blade means, said check valve means comprising a check valve seat formed by adjacent portions of said casing means and blade means, a check valve member cooperable with said check valve seat, and spring means urging said check valve member toward a normally-closed position in engagement with said check valve seat, said blade means being effective to remove excess lubricant from said valve and said check valve means being openable toward said discharge passage means by the removed lubricant.

**5.** An internal combustion engine comprising:
an engine body having a cylinder and valve casing means containing a valve bore and a passage for combustion fluid connecting said valve bore with said cylinder;
a piston operable in said cylinder;
a rotary valve operable in said valve bore and controlling said passage;
supply passage means leading to said valve bore for supplying lubricant to the periphery of said valve;
said casing means having substantially radially disposed slot extending along said valve bore and located in the periphery thereof;
lubricant scraper blade means in said slot and engaging said valve;
lubricant discharge passage means leading from said slot;
check valve means in said slot alongside said blade means being effective to remove excess lubricant from said valve and said check valve means being openable toward said discharge passage means by the removed lubricant;
said valve casing means includes sleeve means comprising curved segments disposed between said valve and the wall of said valve bore;
said slot being formed at least in part by an intervening space between a pair of adjacent edge portions of said curved segments; and
wherein said check valve means comprises a check valve seat formed at least in part by one of said edge portions, and a check valve member normally engaged with said check valve seat.

**6.** An internal combustion engine as defined in claim 5 wherein:
said one edge portion is a beveled edge portion, and said check valve member has an inclined side face normally seated against said beveled edge portion.

**7.** An internal combustion engine as defined in claim 5 wherein
one of said edge portions is a beveled edge portion and the other is a radially disposed edge portion; including
a blade means having one side thereof presented to said radially disposed edge portion; and

wherein said check valve member has a tapered cross-sectional shape formed by inwardly converging said faces and is disposed with one of said side faces lying against said blade means and the other being normally in engagement with said beveled edge portion.

**8.** In an internal combustion engine:

an engine body containing a cylinder, a valve bore and a passage connecting said cylinder with said valve bore;

a piston operable in said cylinder, curved wall means extending around said valve bore;

a rotary valve operable in said valve bore for controlling said passage;

lubricant supply means including delivery opening means in said wall means for supplying lubricant to said valve; and

gas pressure supply means adjacent said valve and operable to deliver gas under pressure during the rotation of said valve, said gas pressure supply means being connected with said delivery opening means for discharging gas into the latter in a contra-flow direction to the supply flow of the lubricant.

**9.** An internal combustion engine as defined in claim **8** wherein:

said gas pressure supply means is a pump means comprising co-operating portions of said wall means and valve.

**10.** An internal combustion engine as defined in claim **9** wherein:

the one of said co-operating portions which is located on said wall means comprises an eccentric peripheral groove in the latter.

**11.** In an internal combustion engine:

an engine body containing a cylinder, a valve bore and a passage connecting said cylinder with said valve bore;

a piston operable in said cylinder;

curved wall means extending around said valve bore and having an opening therein at one point of its periphery and a slot therein at another point of its periphery;

a rotary valve operable in said valve bore for controlling said passage;

lubricant supply means including an orifice member in said opening and having a delivery orifice for supplying lubricant to the periphery of said valve;

gas pressure supply means operable during the rotation of said valve and comprising cooperating portions of said wall means and valve;

said gas pressure supply means having discharge means connected with said lubricant supply means to discharge gas into the latter through said orifice member for controlling the delivery of lubricant to said valve; and

scraper means in said slot and engaging the periphery of said valve.

**12.** An internal combustion engine as defined in claim **11** wherein:

said scraper means comprises a blade for spreading lubricant on the valve periphery and removing excess lubricant therefrom; and

a check valve member adjacent said blade and openable by the scraped-off excess lubricant.

**13.** In an internal combustion engine:

an engine body containing a cylinder, a valve bore and a passage between said cylinder and bore;

a piston operable in said cylinder;

valve casing means in said bore including a substantially rigid tubular casing member and sleeve means in said casing member;

said casing means having a recess therein;

a sealing shoe received in said recess and having a port connected with said passage;

a rotary valve operable in said sleeve means and controlling said port;

means for supplying lubricant under pressure including delivery opening means in said sleeve means for supplying lubricant to said valve; and

gas pressure supply means formed by co-operating portions of said sleeve means and valve and connected with said delivery opening means for discharging gas pressure into the latter for controlling the delivery of lubricant therefrom.

**14.** An internal combustion engine as defined in claim **13** wherein:

said co-operating portions comprise an air pump means having a pump chamber and an air intake passage means connected with said pump chamber.

**15.** An internal combustion engine as defined in claim **13** wherein:

said delivery opening means comprises an orifice member in the wall of said sleeve means; and

wherein said casing member, sleeve means, orifice member, sealing shoe and rotary valve comprise a performed valve assembly unit removably received in said bore.

**16.** In a rotary-valve internal combustion engine:

an engine body containing cylinders in a longitudinal row, and valve bores in a longitudinal row with individual bores extending transversely of the respective cylinders at one end of the latter;

said body having outer and inner walls and intervening space for liquid coolant;

the inner walls being curved walls extending around said valve bores and provided with openings;

pistons operable in said cylinders;

a valve shaft rotatably supported by said body and extending longitudinally of the cylinder row on one side thereof;

valve casing means in said valve bores and comprising substantially rigid tubular casing members having portions thereof exposed to contact by said coolant through said openings;

said casing members having recesses therein on the side thereof adjacent said cylinders;

sealing shoes received in said recesses and having ports in communication with said cylinders;

spaced antifriction bearings mounted in said casing members;

flexible sleeves in said casing members between said spaced bearings;

rotary valves operable in said sleeves and controlling said ports;

contracting means effective on said sleeves for contracting the same around said valves; and

cooperating gear members on said shaft and valves for driving the latter, the casing member, sleeve, contracting means, bearings, sealing shoe and rotary valve associated with each cylinder comprising a preformed valve assembly unit disposed in one of

said valve bores and being removable therefrom as such unit.

**17.** A rotary-valve internal combustion engine as defined in claim **16** and comprising lubricant supply means including feeder openings in the walls of said sleeves; and

gas pressure supply means comprising co-operating portions of said valves and sleeves and having discharge means connected with said feeder openings for supplying gas pressure thereto to control the feeding of the lubricant.

**18.** A rotary-valve internal combustion engine as defined in claim **16** wherein:

said valves have tubular portions containing exhaust gas passages, and the gear members of the valves are mounted on said tubular portions and spaced from the antifriction bearings next adjacent thereto; and

wherein said lubricant supply means comprises other lubricant feeders located at points between the last-mentioned gear members and bearings.

**19.** A rotary-valve internal combustion engine as defined in claim **16** and comprising lubricant supply means including feeder openings in the walls of said sleeves;

said valves having peripheral portions thereof in running contact with the sleeve walls, and lubricant pick-up pockets in said peripheral portions for intermittent lubricant-receiving communication with said feeder openings during the rotation of the valves.

**20.** In a rotary-valve internal combustion engine:

an engine body having a cylinder, and valve casing means providing a valve bore at one end of the cylinder;

a piston operable in said cylinder;

bearing means associated with said valve bore;

flexible sleeve means in said valve bore;

a rotary valve supported by said bearing means and operable in said sleeve means for controlling intake and exhaust communication with said cylinder;

said sleeve means having beveled end portions being supported in a floating relation between the wall of said bore and said valve for expanding and contracting movements relative to the latter;

contracting means effective on said sleeve means for contracting the same around the valve, said contracting means comprising ring members adjacent the ends of said sleeves and having tapered portions presented toward said beveled portions; and

spring means urging said tapered portions into engagement with said beveled portions for normally contracting said sleeve means around said valve.

**21.** A rotary-valve engine as defined in claim **20** wherein:

said ring members are shiftable in said casing means to provide for the floating relation of said sleeve means and comprise heat-conducting rings effective to conduct heat from said sleeve means to said casing means.

**22.** An internal combustion engine comprising:

an engine body having a cylinder, and valve casing means providing a valve bore at one end of the cylinder;

a piston operable in said cylinder;

bearing means associated with said valve bore;

flexible sleeve means in said valve bore;

a rotary valve supported by said bearing means and operable in said sleeve means for controlling intake and exhaust communication with said cylinder;

said sleeve means having beveled end portions being supported in a floating relation between the wall of said bore and said valve for expanding and contracting movements relative to the latter;

contracting means effective on said sleeve means for contracting the same around the valve, said contracting means comprising ring members adjacent the ends of said sleeves and having tapered portions presented toward said beveled portions; and

spring means urging said tapered portions into engagement with said beveled portions for normally contracting said sleeve means around said valve;

said sleeve means is split longitudinally at one point thereof and has relatively stationary and relatively free segment portions on opposite sides of the split;

anchor means engaged by the stationary segment portion;

said sleeve means being self-expanding in opposition to said contracting means by circumferential shifting of said free segment portion; and

the expanding of said sleeve means being in response to an unwrapping tendency thereof in relation to said valve during the rotation of the latter.

**23.** An internal combustion engine as defined in claim **22** wherein:

said rotary valve has radially-opening intake and discharge passes therein for intake and exhaust communication; and

a pick-up pocket, said pick-up pocket being located on the valve on the trailing side only of the intake passage opening.

**24.** In a rotary-valve internal combustion engine:

an engine body having a cylinder, and valve casing means providing a valve bore at one end of the cylinder;

a piston operable in said cylinder;

a rotary valve controlling intake and exhaust communication with said cylinder and operable in said valve casing means with a peripheral portion of the valve in running contact with the wall of said valve bore;

lubricant supply means including delivery opening means in said wall;

gas pressure supply means comprising recess means in said wall on one circumferential side of said opening means; and

said peripheral portion having a pick-up pocket therein located for communication with said opening means and recess means in succession during the rotation of said valve.

**25.** An internal combustion engine as defined in claim **24** wherein:

said recess means comprises an arcuately extending pump chamber having an air intake connection;

the rotation of said valve being effective to pressurize air in said pump chamber;

said pocket being effective to carry a quantity of lubricant away from said delivery opening means for spreading on said peripheral portion; and

being also effective to transfer pressurized air from said pump chamber to said delivery opening means for controlling the delivery of oil through the latter.

**26.** An internal combustion engine as defined in claim **25** wherein:

said wall has a slot therein on the other circumferential side of said opening means and spaced from the latter; and

scraper means located in said slot and engaging said peripheral portion.

**27.** An internal combustion engine as defined in claim **25** wherein:

said wall has a slot therein on the other circumferential side of said opening means and spaced from the latter; and

scraper means and an adjacent check valve means located in said slot, said scraper means being in engagement with said peripheral portion for spreading lubricant thereon and removing excess lubricant therefrom, and said check valve means being openable by the scraped-off excess lubricant.

**28.** In an internal combustion engine:

an engine body having a cylinder, a valve bore and a connecting passage between said cylinder and bore;

a piston operable in said cylinder;

tubular valve casing means in said bore and having a side opening substantially opposite said passage, and an annular recess surrounding said opening and including an annular seat at the bottom of said recess;

a sealing shoe received in said recess and having a port connected with said passage;

a rotary valve engaged by said shoe and operable in said casing means for controlling intake and exhaust communication with said cylinder through said port;

said shoe having a relatively reduced portion in cooperative relation to said seat and defining with adjacent portions of said casing means an annular packing recess extending around said reduced portion; and

packing ring means confined in said packing recess and comprising at least two expansible and contractible sealing and heat-conducting metal rings, and a spring ring interposed between said seat and said metal rings, said metal rings having beveled-annular surfaces thereon maintained in cooperative wedging engagement by the action of said spring ring.

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