United States Patent

[11] 3,610,210

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[33] **Japan**
[31] **44-33070 and 44-16188**

[54] **MACHINE OF THE ROTARY BLADE TYPE**
11 Claims, 15 Drawing Figs.

[52] **U.S. Cl.** **123/8.35,** 123/8.05, 123/8.07, 418/210, 418/238, 418/255, 418/256, 418/265

[51] **Int. Cl.** **F02b 55/02,** F02b 53/06, F01c 19/10

[50] **Field of Search** 123/8.01, 8.35, 8.05; 418/117, 147, 148, 255, 259, 256, 265, 254, 253

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Primary Examiner—Mark M. Newman
Assistant Examiner—Alan G. Goedde
Attorney—McGlew and Toren

ABSTRACT: A machine of the rotary blade type in which a rotor having discal members fixed mounted on its opposite end surfaces is rotatably and eccentrically mounted in a casing. At least a telescopic blade comprising a plurality of blade portions is mounted for sliding motion in a blade groove formed to extend through the rotor and the discal members are formed with grooves for supporting and guiding the telescopic blade. Support means are arranged in two rows on the outsides of the discal members for positioning respective blade portions, the support means being parallel to each other and mounted rotatably. Two telescopic blades can be disposed in two parallel blade grooves formed to extend through the rotor.

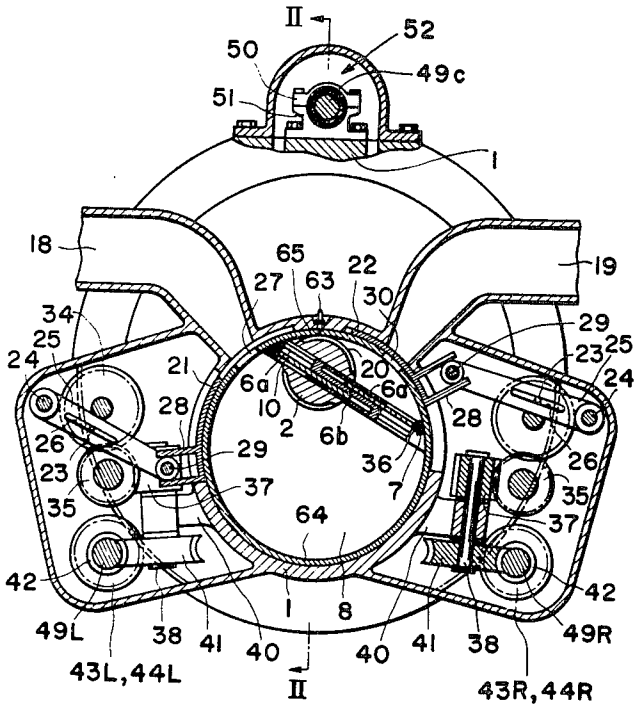
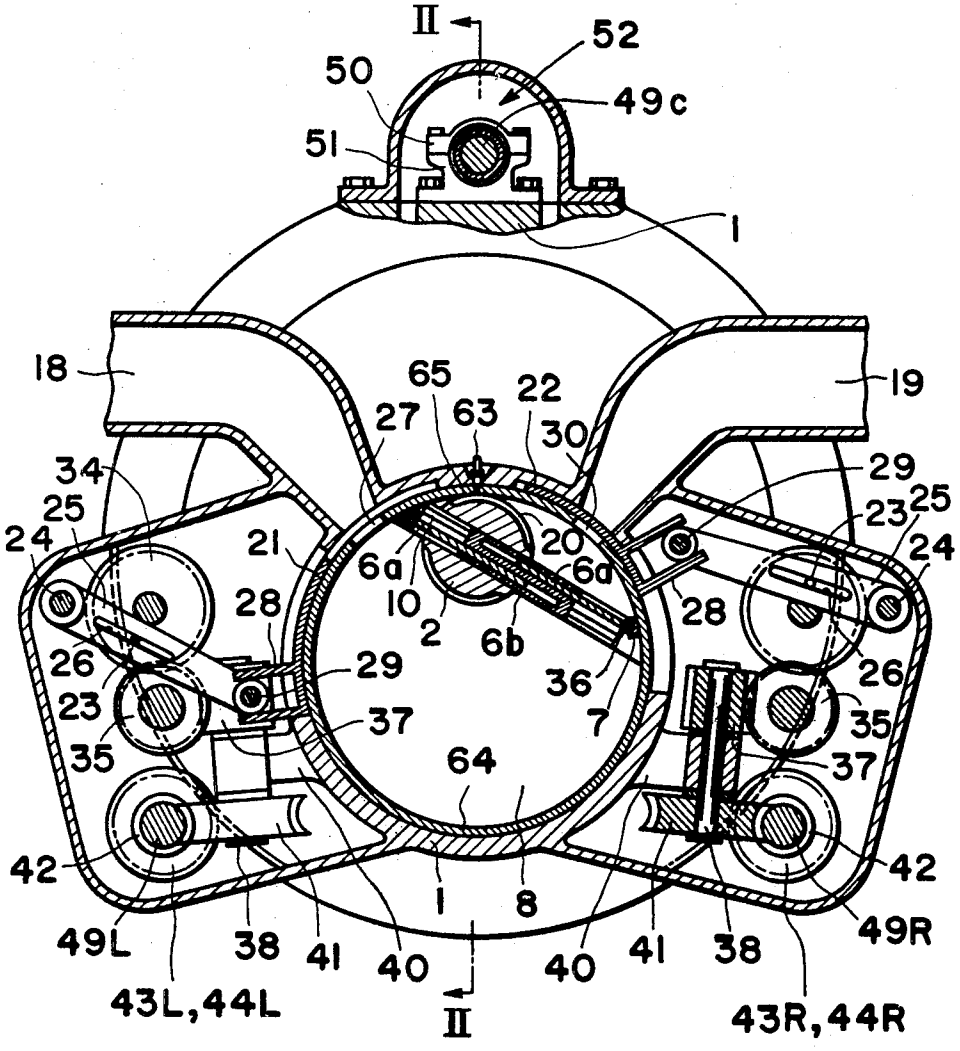


FIG 1



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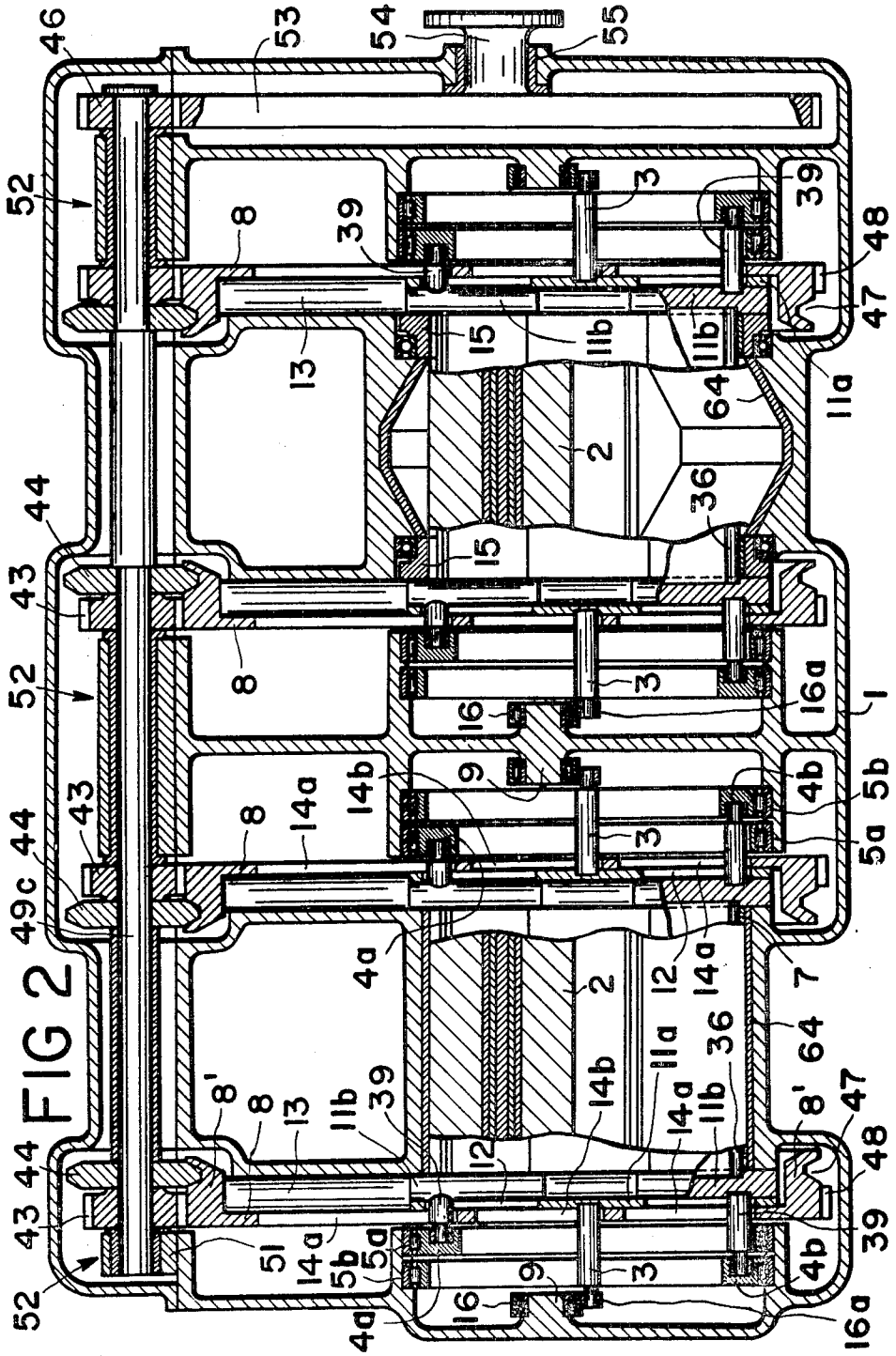


FIG 2

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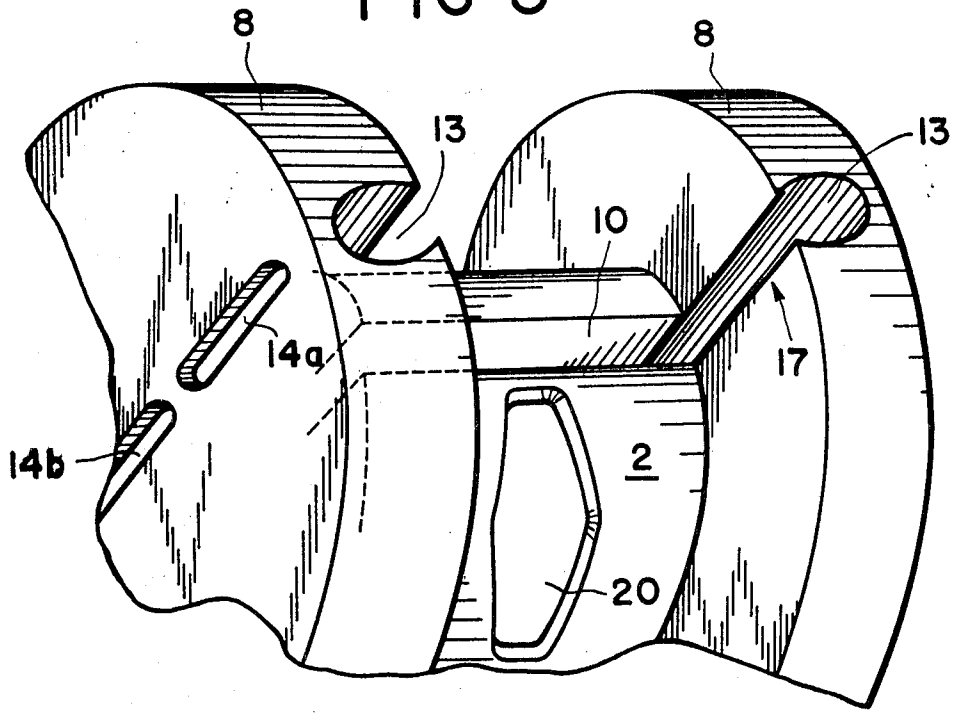
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FIG 3



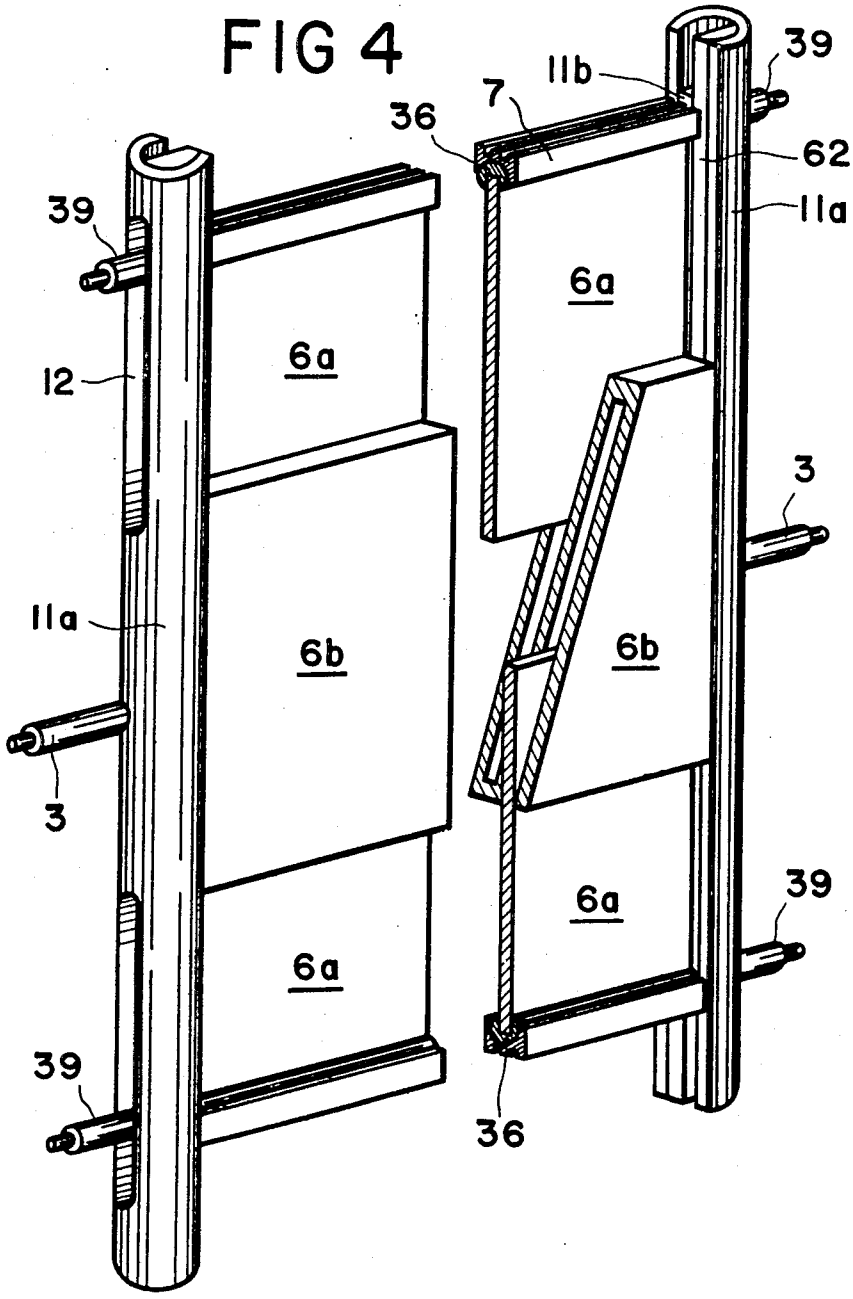
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FIG 4



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FIG 5

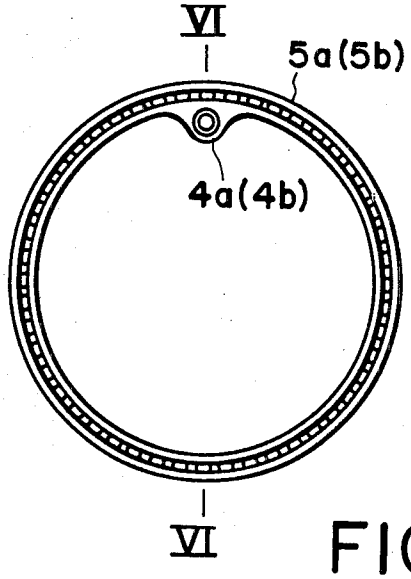


FIG 6

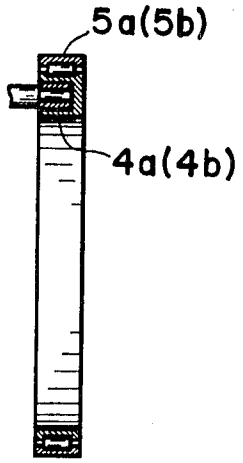


FIG 7

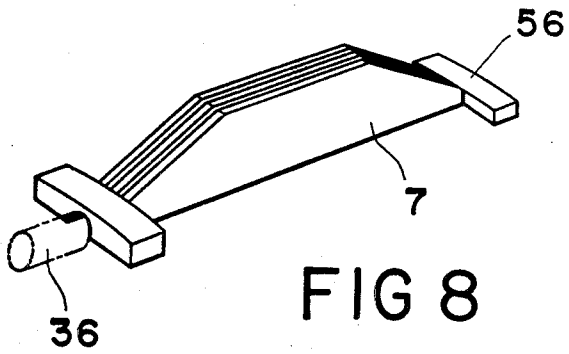
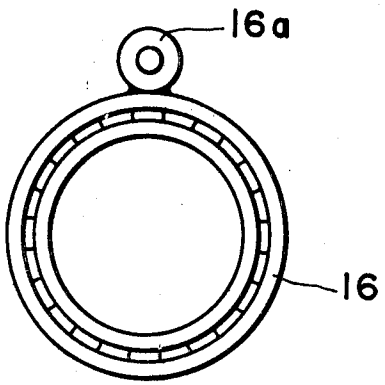


FIG 8



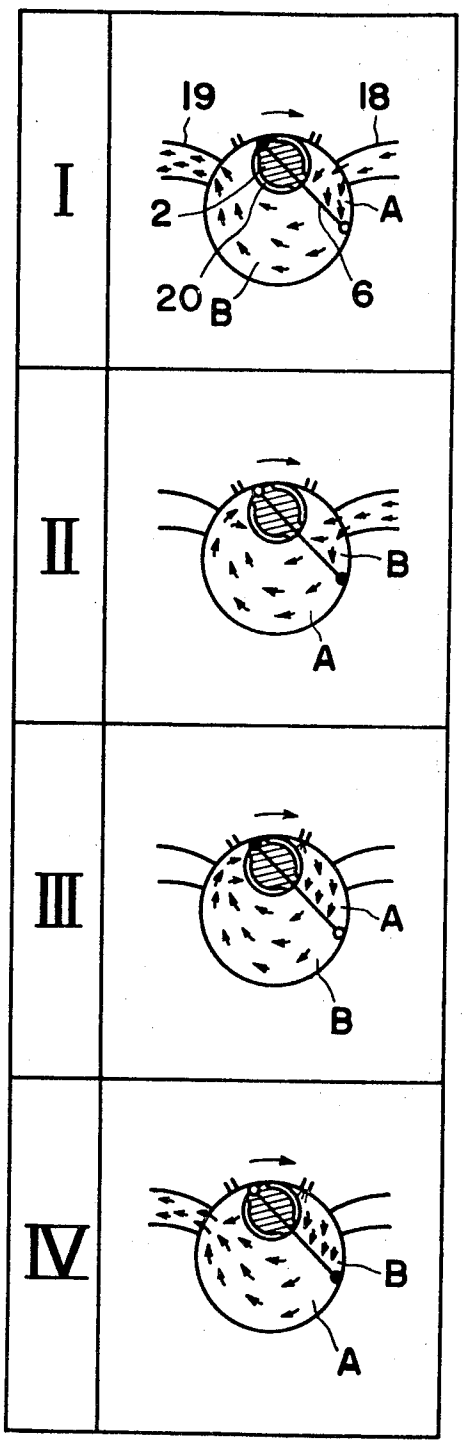
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FIG 9



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FIG 10

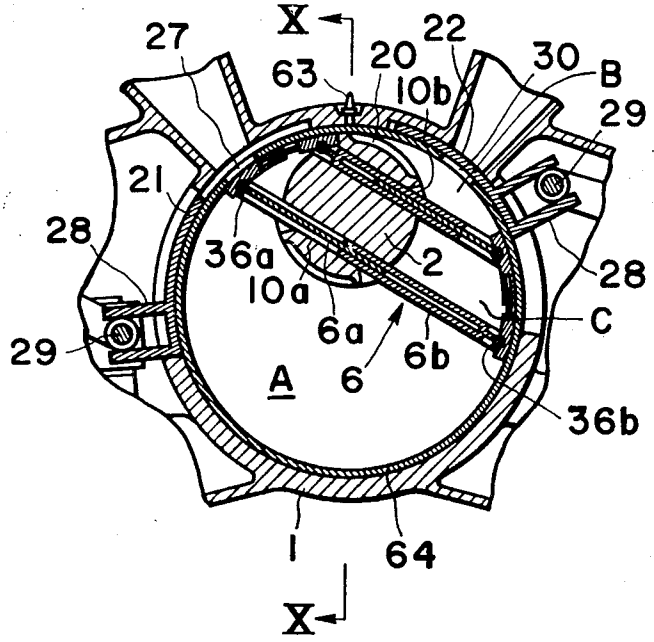
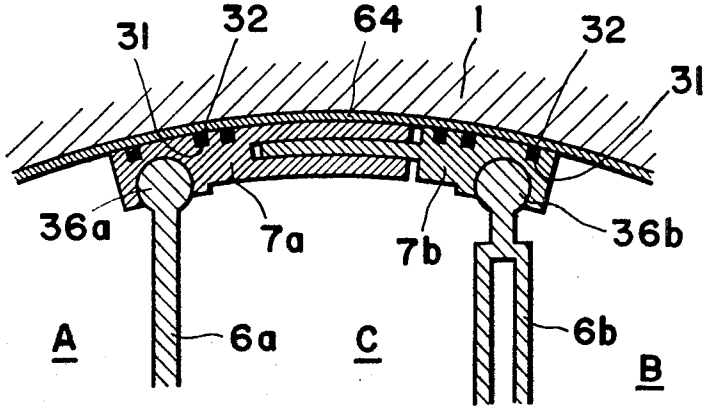


FIG 11



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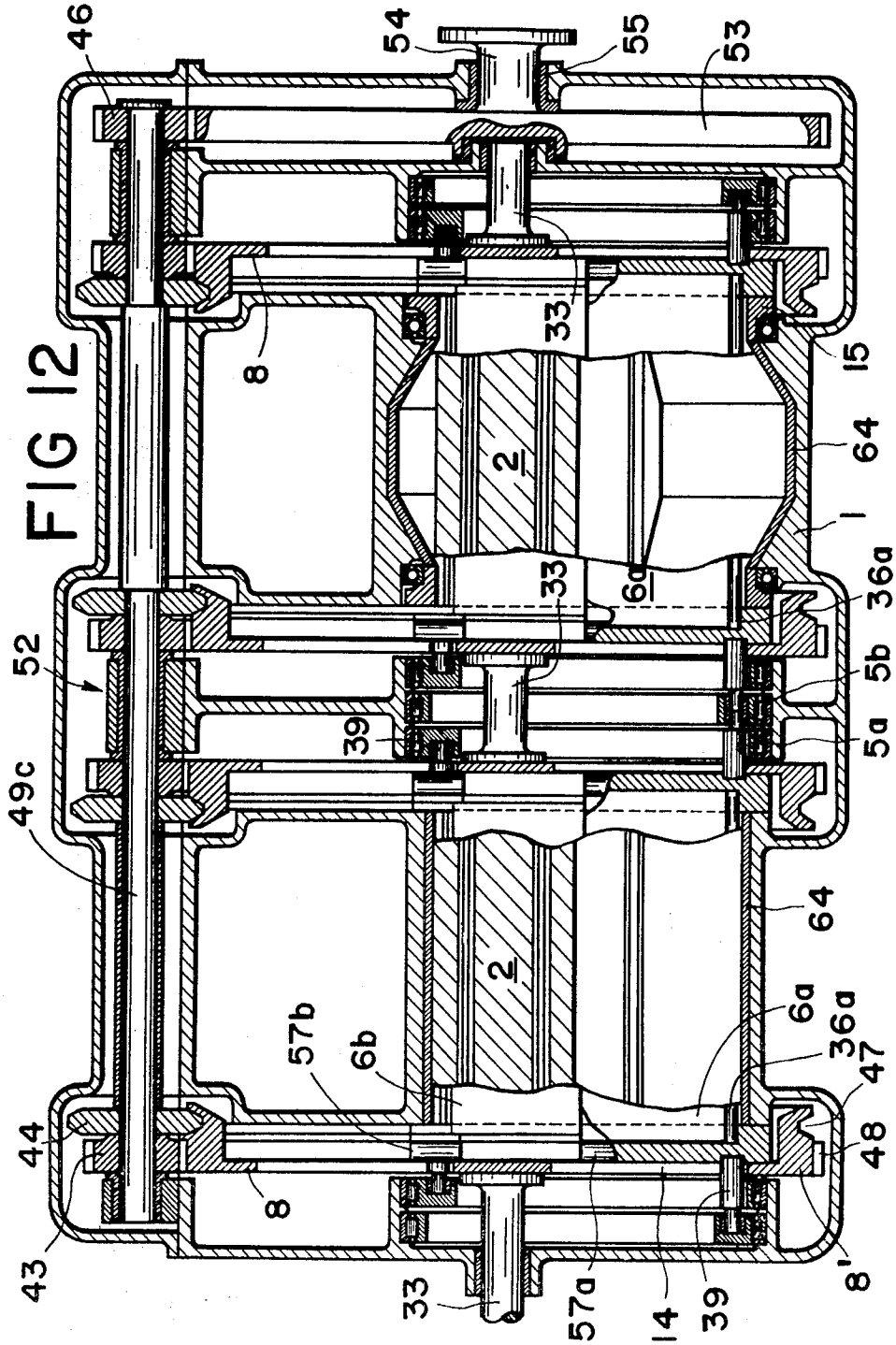
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FIG 12



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FIG 13

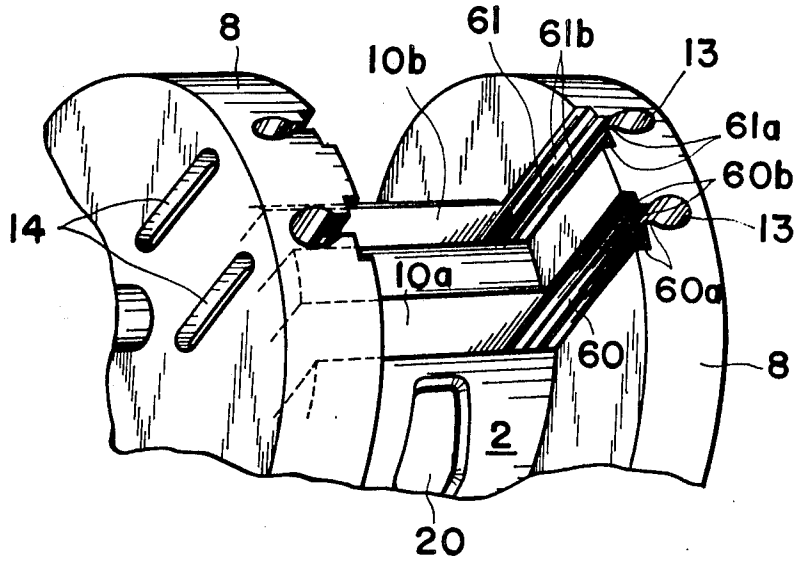
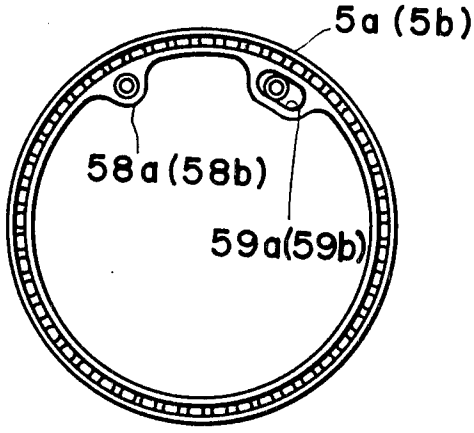


FIG 15



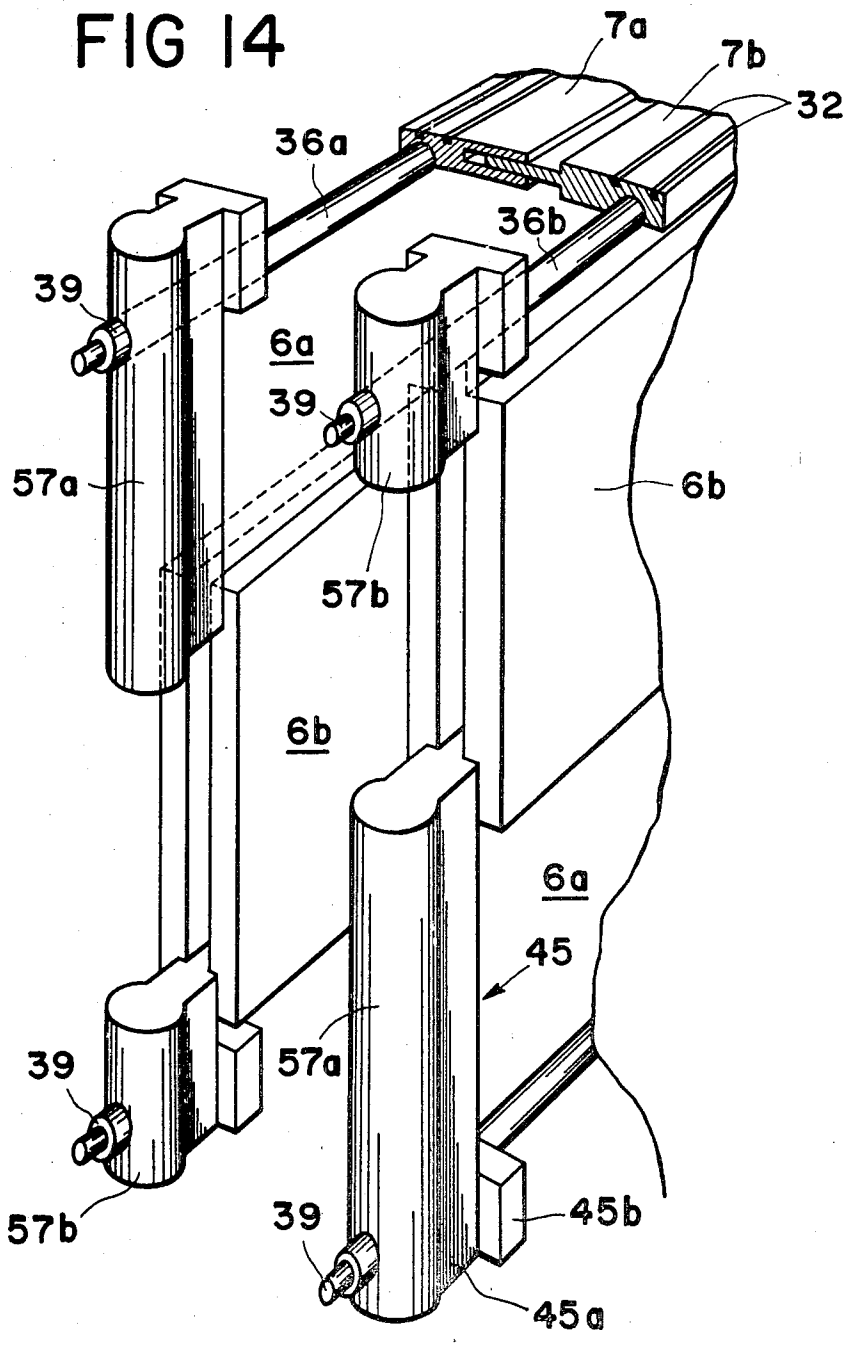
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FIG 14



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MACHINE OF THE ROTARY BLADE TYPE

This invention relates to machines of the rotary blade type in which a rotor is eccentrically mounted for rotation in a casing and blades are arranged on the rotor for movement radially of the rotor so that the volume of the work chambers may be varied as the rotor rotates.

Conventional machines of the type described have had the disadvantage of being unable to increase, beyond a certain level, the eccentricity of the rotor relative to the casing due to difficulties encountered in ensuring the strength of the rotor carrying the blades and formed with grooves for mounting the blades therein and preventing the leaking of the working medium. Proposals have been made to use blades of a fixed length which are arranged to extend through the center of the rotor for sliding movement and to construct the casing such that the inner surface thereof corresponds to the locus of movement of the forward ends of the blades. This arrangement is not without a disadvantage. Since the inner surfaces of the blades are not shaped as a true circle and very irregular in shape, it is impossible to maintain the forward ends of the blades in intimate contact with the inner surface of the casing at all times. Moreover, when the forward ends of the blades are pushed by the inner surface of the casing, the working medium is compressed and exerts high forces on the blades to forcedly bend the same. The blades must be tough and firm in construction enough to withstand the forces exerted thereon by the working medium and maintain their forward ends intimate contact with the inner surface of the casing. However, the blades constructed as aforementioned are liable to bite into the inner surface of the casing, resulting inevitably in causing damage to the forward ends of the blades and inner surface of the casing. In an effort to provide an improvement in the machines of the rotary blade type referred to in the opening paragraph, the present inventor has already proposed to fixedly mount a discal member on each side of the rotor and airtight rotor are mounted in enclosing relationship with the discal members. The discal members are formed with radially arranged grooves for supporting the blades and guiding the same in their sliding movement, and the airtight rotors are maintained in intimate contact with the forward ends of the blades and adapted to rotate concentrically with the casing with which they maintain contact through antifriction means, so that the airtight rotors rotate in slaved relation with the rotor. This arrangement permits the grooves in the discal members to support the blades therein so as to eliminate forces which would otherwise be exerted on the blade grooves of the rotor by the blades supported therein, and makes it possible to use telescopic blades. At the same time, the arrangement permits the discal members to bear the axial thrust applied to the working chamber to thereby remove disadvantages which might otherwise result from the thrust being applied directly to the casing.

The improved construction described above offers many disadvantages. Since it is possible to form the casing in the shape of a true circle, processing operations are facilitated. By mounting the blades such that they are suspendedly mounted at their forward ends, it is possible to ensure that the blades are disposed in predetermined circumferential and radial positions and the forward ends of the blades are maintained in intimate contact with the inner surface of the casing at all times. Moreover, the use of the telescopic blades supported in the grooves formed in the discal members permits to increase the eccentricity of the rotor. An increase in the eccentricity naturally causes an increase in the amount of delivery or the compression ratio, thereby increasing the range of application of the rotary machine of the blade-type described.

A principal object of this invention is to provide a machine of the rotary blade type which represents an improvement in the aforementioned construction for particularly adapting the machine for use as an internal combustion engine.

Another object of the invention is to provide a machine of the rotary blade-type described which has a high compression ratio relative to the eccentricity of the rotor and in which means is provided for facilitating the cooling of the blades and rotor.

Other objects as well as features and advantages of the invention will be evident from the description set forth hereinafter when considered in conjunction with the accompanying drawings, in which:

FIG. 1 is a sectional view of an embodiment of the machine of the rotary blade type according to this invention which is constructed as an internal combustion engine;

FIG. 2 is a sectional view taken along the line II—II of FIG. 1 showing two different embodiments of the machine according to this invention being arranged in side-by-side relationship;

FIG. 3 is a perspective view of the rotor used in the present invention, with the ring-shaped portions of the discal members being omitted;

FIG. 4 is a perspective view, with certain parts being shown in section, of the blade used in the present invention;

FIG. 5 is a plan view of support means for the platelike blade portion;

FIG. 6 is a sectional view taken along the line VI—VI of FIG. 5;

FIG. 7 is a perspective view of a packing slider;

FIG. 8 is a plan view of supporting means for the S-shaped blade portion;

FIG. 9 is a view in explanation of the cycles of operation of the internal combustion engine of the rotary blade type according to this invention;

FIG. 10 is a sectional view of a second embodiment of the machine of the rotary blade type according to this invention;

FIG. 11 is a sectional view showing the packing sliders mounted on the forward ends of the blades of the second embodiment;

FIG. 12 is an axial sectional view similar to FIG. 2 which is taken along the line X—X of FIG. 10;

FIG. 13 is a perspective view of the rotor of the second embodiment, with the ring-shaped portions of the discal members being omitted;

FIG. 14 is a perspective view of the sliders and sliding portions arranged on one side of the blades; and

FIG. 15 is a plan view of a rotary supporting member for use in the second embodiment.

The invention will now be explained with reference to embodiments shown in the accompanying drawings. In FIG. 1, a rotor 2 is mounted eccentrically in a casing 1 for rotation therein. Extending through the rotor 2 is a blade groove 10 in which two telescopic blades are mounted to be disposed at an angle of 180 ° relative to each other. Each telescopic blade comprises two blade portions 6*a* and 6*b*. The blade portions 6*b* of the two blades are U-shaped and fixed to each other in side-by-side relation to form an S-shaped unit. Secured to the forward end of the platelike blade portion 6*a*, 6*a* is a blade-supporting shaft 36 which is enclosed by a packing slider 7 rotatably mounted around the shaft 36. This arrangement provides a seal to the working chamber to prevent the leaking of the medium and, at the same time, prevents the packing sliders 7, 7 from pressing against a liner 64 of the casing 1 due to an excessively high pressure applied thereto by centrifugal forces. If the inner circumferential surface of the casing 1 is not cylindrical but concaved in shape to increase the stroke volume as is the case with the embodiment shown on the right side in FIG. 2, then the packing sliders 7, 7 may be of the convexed shape complementary with the concaved shape of the inner circumferential surface of the casing (see FIG. 7).

If this is the case, the packing sliders 7,7 may be each formed with sliding pieces 56, 56 on their opposite ends which are maintained in intimate contact with airtight rotors 15,15 mounted concentrically with the casing 1 through antifriction means on opposite sides of the working chamber, so that the packing sliders 7, 7 can be disposed radially at all times.

The rotor 2 is formed in its surface with recesses 20 as shown in FIGS. 1 and 3. The liner 64 of the casing 1 and the rotor 2 are brought into contact with each other at a contact position 65. Thus, the medium in the working chamber disposed rearwardly of the contact position 65 as seen in the direction of rotation of the rotor 2 is excessively compressed

so that a failure may be caused. In order to avoid such failure, the recess **20** serves as a bypass through which the medium in the rearward portion of the working chamber is permitted to flow into the front portion thereof.

An ignition plug **63** is mounted in the contact position **65**. The casing is formed with an inlet passageway **18** and an outlet passageway **19**. Other parts of the construction shown in FIG. **1** are subsequently to be described.

In FIG. **2**, two different embodiments of the machine of the rotary blade type according to this invention are shown on the left and right sides. In each embodiment, discal members **8, 8** are arranged on opposite sides of the rotor **2** at right angles to the axis of the rotor **2**. As shown in FIG. **3**, the discal members **8, 8** are each formed with a radial cylindrical space **13** and radial groove **17** maintaining communication with each other. The grooves **17** maintain communication with the blade groove **10** formed in the rotor **2**, so that the S-shaped blade portion **6***b*can move in sliding motion in the radial grooves **17** and blade groove **10**. The cylindrical spaces **13, 13** formed in the discal members **8, 8** respectively and disposed in side-by-side relationship each have a slot **14***a* formed alongside the respective cylindrical spaces and extending through the discal members **8, 8**. The major dimension of the slots **14***a*, **14***a* have a length corresponding to the range movement of the blade portions **6***a*, **6***a*. Another slot **14***b* is formed alongside the cylindrical space **13** of each discal member **8** to extend through the center portion thereof. The slots **14***b*are subsequently to be described in detail. A ring-shaped portion **8'** is formed integrally with each discal member **8** to be disposed on the outer surface thereof as shown in FIG. **2**. A V-shaped annular groove **47** and gear **48** are arranged on the outer circumferential surface of each ring-shaped portion **8'**. The ring-shaped portions **8', 8'** are omitted from the discal members **8, 8** shown in FIG. **3**.

In conventional machines of the rotary blade type, power is usually transmitted and taken out through a shaft connected to the rotor. However, the use of the rotor and shaft connected together as means for transmitting power may cause a trouble in the machine of the rotary blade type constructed as aforesaid, because the eccentricity of the rotor with respect to the casing is very high and the blade groove **10** extends through the central portion of the rotor. In order to obviate this disadvantage, three parallel shafts **49C, 49L** and **49R** are mounted on the outer side of the discal members **8, 8** fixed to the rotor **2**, said parallel shafts being disposed around the rotor **2** and arranged equidistantly from one another at an angle of 120 ° as shown in FIG. **1**. A pinion **43** and friction wheel **44** are fixed to each of the parallel shafts within the zone of each discal member **8** as shown in FIG. **2**. The pinion **43** is maintained in engagement with a gear **48** disposed on the ring-shaped portion **8'** of each discal member **8**, and the friction wheel **44** is maintained in engagement with a V-shaped circumferential groove **47** in each ring-shaped portion. As shown in FIG. **2**, a thrust metal is arranged in a center bearing portion **52** for the pinions **43**.

By using the thrust metal as a reference, each pinion **43** and each friction wheel **44** can be accurately positioned as by spacer sleeve. This arrangement is used for all the shafts **49C, 49L** and **49R**. Thus, the end surfaces of the center bearing portions **52** for all the shafts **49C, 49L** and **49R** are disposed in the same plane while are normal to the shafts, and consequently the friction wheels **44** of all the shafts and the V-shaped circumferential grooves **47** in engagement with the friction wheels are disposed in a plane normal to the shafts. This permits the discal members **8, 8** to be disposed in a plane normal to the shafts, so that the rotor fixed to the discal members is disposed on its normal center axis. The gears **43** perform the function of both transmitting power developed in the working chamber to the outside and transmitting power from outside to the blades and rotor. Since the gears **43** engage the right and left discal members **8, 8** of the rotor in three positions, twisting of the discal members **8, 8** due to uneven transmission of power from the working chamber to the discal members **8, 8** or from the discal members **8, 8** to the working chamber can be avoided. The friction wheels **44** and circumferential grooves **47** in the discal members **8, 8** perform the function of supporting the discal members **8, 8** in three positions and for bearing the axial thrust. It is to be understood in this connection that the shape of the grooves and circumferences of the friction wheels is not limited to the illustrated V-shaped The friction wheels and grooves may be of any shape as desired, so long as they can perform the function assigned to them as aforementioned.

As shown in FIG. **1**, the bearing portion **52** of the shaft **49C** alone comprises a bearing bed **51** removably fixed to the casing **1** and an upper bearing portion **50**. The bearing portions **52** of other shafts **49L** and **49R**, which are not shown in the interest of brevity, may have their bearing beds **51** formed integrally with the casing. The arrangement that the bearing bed **51** is removably fixed to the casing **1** makes it possible to compensate, by suitably replacing or removing shims or other position adjusting means inserted between the casing **1** and the bearing bed **51**, for a gap that might be formed between the friction wheels **44** and the circumferential grooves **47** in the discal members **8, 8** when the friction wheels are worn.

In FIG. **2**, a gear **46** is mounted on the right end of each of the shafts **49C, 49L** and **49R** for meshing engagement with a gear **53** formed integrally with or mounted on a shaft **54** rotatably journalled by a bearing portion **55** of the casing **1**, whereby power can be transmitted to or supplied from outside. It is to be understood that by suitably selecting the diameters of the gears **46** and **53**, it is possible to select any number of revolutions for the shaft **54**.

As shown in FIGS. **2** and **4**, the shafts **36** for suspending the blade are fixed to minor sliders **11***b*, **11***b*slidably mounted in concaved portions of major sliders **11***a*, **11***a*. Fixed to each of the minor sliders **11***b*, **11***b* is another shaft **39** which is coaxial with the shaft **36** and extends through an axial slot **12** formed in the major sliders **11***a*, **11***a* and the slot **14***a* formed in one of the discal members **8,8**. The concaved portion of each major slider **11***a* is constructed as a cylindrical inner surface in which a filling member **62** is fixedly mounted to prepare a guide groove for the minor slide **11***b*. The major sliders **11***a*, **11***a* which are slidably fitted in the cylindrical spaces **13, 13** of the discal members **8, 8** are fixed, at their central portions, to opposite sides of the S-shaped blade portion **6***b* so that the major sliders **11***a*, **11***a* and the blade portion **6***b* form an H-shaped unit.

Projecting outwardly through each of the major sliders **11***a*, **11***a* from the outer central portion thereof is a supporting shaft **3** which extends through the slot **14***b* formed in one of the cylindrical spaces **13, 13** of the discal members **8, 8** and which has a minor diameter forward end portion rotatably received in a supporting portion **16***l* (see FIG. **8**) of a supporting rotary member **16** mounted on a boss **9** attached to the casing **1** as shown in FIG. **2**. Thus, the supporting shafts **3** are guided by the supporting portions **16***a* to rotate about the supporting members **16** as the rotor **2** rotates, whereby the positioning of the S-shaped blade portion **6***b* fixed to the shafts **3** can be effected radially of the rotor **2**. The supporting shafts **3** may be mounted on the supporting portions **16***a* of the supporting rotary members **16** through antifriction means.

The shafts **39, 39** are supported by a supporting portion **4***a* and **4***b* of supporting rotary members **5***a* and **5***b* (FIG. **5**) respectively mounted for rotation in the casing **1** and disposed concentrically with its inner cylindrical surface. The supporting rotary members **5***a* and **5***b* are disposed in side-by-side relationship. The shafts **39, 39** connected respectively to the two blade portions **6***a*, **6***a* adapted to move in opposite directions and to be telescopically received in the S-shaped blade portions **6***b* are supported by the supporting portions **4***a* and **4***b* of different supporting rotary members **5***a*, **5***b*. Thus, two shafts **39, 39** of different lengths are provided for the supporting rotary members **5***a*, **5***b*. The shafts **39, 39** are rotatably supported by the supporting portions **4***a* and **4***b* respectively through antifriction means. Since the rotor **2** is mounted ec-

centrically with respect to the inner surface of the casing 1, the forward ends of the two blade portions 6a, 6a telescopically received in the S-shaped blade portion 6b or the shafts 36, 36 and 39, 39 connected to the forward ends of the blade portions 6a, 6a have peripheral velocities which are not constant and which vary from time to time. This makes it impossible to suspend the two shafts 39, 39 of the two blade portions 6a, 6a from the same supporting rotary member, making it necessary to suspend them from different supporting rotary members. The arrangement in which the shafts 39, 39 are supported by the supporting rotary members 5a and 5b permits the forward ends of the blade portions 6a, 6a to be maintained in intimate contact with the inner surface of the working chamber in airtight relation at all times.

In the embodiment shown on the right side of FIG. 2, the ring-shaped airtight rotors 15, 15 are provided to face the working chamber so that the sliding pieces 56, 56 are disposed on opposite sides of the packing slider 7 may be supported by the airtight rotors 15, 15 when centrifugal forces are at work. Since the airtight rotors 15. 15 are mounted concentrically with the inner surface of the casing 1 and rotatable through antifriction means, they rotate in slaved relation with the sliders 7, 7 at substantially the same speed. Thus, there is a very little difference between the relative speeds of the packing sliders and airtight rotors, and this consequently causes very little wear on the sliders 7.

The form of the machine on the left side of FIG. 2 has a construction such that each packing slider 7 encloses the blade supporting shaft 36 for a circumferential extent on the order of over 180° so as to prevent dislodging of the slider from the shaft 36 which might otherwise be caused by centrifugal forces. Thus, the construction of this embodiment permits to eliminate the airtight rotors 15.

In the form of the machine described, two blades mounted at an angle of 180° relative to each other are used as shown in FIGS. 1 and 4, each of the blades comprising the platelike blade portion 6a and U-shaped blade portion 6b, the two U-shaped portions 6b, 6b being secured together in side by side relation to provide an integral S-shaped unit for permitting the two platelike portions 6a, 6b to simultaneously move into and out of the U-shaped blade portions 6b in telescopic motion. This arrangement is used for the embodiments in which the eccentricity of the rotor is relatively great. If the eccentricity is not so great, then it is not required to form the two U-shaped blade portions into an integral S-shaped unit.

The construction described above can be applied to internal combustion engines, pumps, compressors and the like. When a noncompressible fluid is used as a medium, suction and discharge may be left open. In cases where a compressible fluid is used, however, it is required to provide a valve in each of the suction and discharge ports. The machine according to this invention will further be explained with reference to an embodiment used as an integral combustion engine of the electric ignition type. As shown in FIGS. 1 and 2, the liner 64 is attached to the inner surface of the casing 1 which may be replaced at any time as desired. The liner 64 mounted such that there is substantially no clearance between the liner 64 and the rotor 2 at the contact position 65. In order to enhance the sealing effect in the position 65, antileak packing may be mounted either on the surface of the rotor or on the surface of the liner 64 in the position 56.

Suction and discharge ports 27 and 30 connected respectively with the inlet passageway 18 and outlet passageway 19 formed in the casing 1 are formed in the liner 64 on opposite sides of the contact portion 65. Sliding valves 21 and 22 inserted between the casing 1 and liner 64 are provided for the suction and discharge ports 27 and 30 respectively so as to open and close the suction and discharge ports 27 and 30 in synchronism with the operation of the machine. The mechanism for effecting the opening and closing of the ports will presently be described.

In FIG. 1, a worm 42 is mounted on the power transmitting shaft 49L which is in meshing engagement with a worm wheel 41 fixed to one end of a shaft 38 supported by a bearing portion 40 of the casing 1. Mounted on the other end of the shaft 38 is a screw gear 37 which is in meshing engagement with a gear 35 which in turn is in meshing engagement with a gear 34. The number of revolutions of the gear 34 is set at one-half that of the rotor 2. Attached to the gear 34 is a pin 23 which is engaged in a slot 26 formed in a lever 25 pivotally connected to a pin 24 secured to the casing 1, so that it can move in sliding motion within the range of the slot 26. Attached to the free end of the lever 25 is a drive pin 29 adapted to be received in a groove in a holder 28 of the sliding valve 21. This arrangement permits to convert the rotational movement of the gear 34 into pivotal movement of the lever 25 about the pin 24 and then into a sliding movement of the sliding valve 21 for opening and closing the port 27. It is to be understood that the rate of movement of the sliding valve 21 is not constant; its rate of movement in a direction in which the port is opened is lower than its rate of movement in a direction in which the port is closed. If desired, it is possible to leave the suction port open till the end of the suction stroke, thereby permitting to enhance the suction efficiency.

While the opening and closing mechanism for the suction port 27 has been described hereinabove, similar mechanism mounted on the right side of FIG. 1 is used for opening and closing the discharge port 30. The construction and operation of this mechanism are similar to those of the mechanism for the port 27, so that its description is omitted.

Suction and discharge valves of the butterfly valve type may be used in place of the sliding valves 21 and 22. Also, two ignition plugs may be mounted on each side of the position 65 in place of one ignition plug mounted in the contact position 65 between the rotor 2 and the inner surface of the casing 1 as shown in FIG. 1, so that either one of the ignition plugs can be used in conformity with the direction of rotation of the rotor for reversing the operation of the engine.

Alternatively, a fuel ejection valve or valves may be provided in a position or positions in which the ignition plug or plugs are mounted to provide a Diesel engine.

As aforementioned, the rotor 2 is brought into intimate contact with the liner 64 at the contact position 65 with no clearance therebetween, thereby dividing the working chamber into two portions. The portion of the medium in the working chamber portion which is disposed rearwardly with respect to the direction of movement of the rotor 2 is pronouncedly compressed as the volume of the working chamber portion is reduced. To avoid this phenomenon, the recess 20 is formed on the surface of the rotor so as to maintain communication therethrough between the front working chamber portion and rear working chamber portion divided at the position 65 (FIGS. 1 and 3). By virtue of this arrangement, the portion of medium in the rear working chamber portion moves in a jet stream into the front working chamber portion after the platelike blade portion 6a has moved past the position 65. The turbulent flow of the medium caused to develop by the movement of the medium from the rear working chamber portion to the front working portion in a jet stream permits to render the air-fuel mixture into a homogeneous state. This is advantageous not only in effecting electric ignition of the air-fuel mixture but also in letting the machine operate in the Diesel cycle because the homogeneous air-fuel mixture permits self-ignition possible in the latter case. Two or more recesses may be provided in place of one recess 20 to render the turbulent flow directional so that a secondary turbulent flow may be produced.

Preferably, the explosion is caused to occur when the blades 6, 6 are disposed substantially horizontal or have slightly passed the horizontal position in FIG. 1. Since the time required for combustion is constant irrespective of the number of revolutions, it will be required to suitably increase the angular displacement of the ignition position or gas ejection nozzle position in proportion to an increase in the number of revolutions in order to cause the explosion to take place when the blades are in the aforementioned position in spite of

the increase in the number of revolutions. In the embodiment of the machine of the rotary blade type used as an internal combustion engine, two working chambers displaced by 180° from each other are disposed on opposite sides of the two axially aligned blades. The suction, compression, explosion and discharge strokes take place in each of the working chambers while the rotor **2** makes two complete revolutions as is the case with a four cycle reciprocating engine. This operation will be explained with reference to FIG. **9**. The two working chambers will be designated A and B respectively.

In the first stage of operation I shown in FIG. **9**, the working chamber A is in its suction stroke while the working chamber B is in its discharge stroke. In the second stage II, the working chamber A is in its compression stroke while the working chamber B is in its suction stroke. In the third stage III, the working chamber A is in its explosion stroke while the working chamber B is in its compression stroke. In the fourth or final stage IV, the working chamber A is in its discharge stroke while the working chamber B is in its explosion stroke. It will be understood that the strokes of working chamber A are ahead of the stroke of working chamber B by 180°.

Alternatively, the working chamber B may be in its compression stroke in place of the discharge stroke in the first stage I. In this case, the working chamber B will be in the explosion, discharge and suction strokes in the second II, third and fourth stages III, IV respectively. Thus, the strokes of the working chambers B will be ahead of the strokes of the working chamber A by 180°.

In the aforementioned case, the suction angle 180° of the working chamber A is followed by the suction angle of 180° of the working chamber B, so that the suction port can be made to remain open through one complete revolution of the rotor **2**. The same is true of the discharge port. In this case, the discharge port will begin to open after the revolution of the rotor through 180° following the closing of the suction port, and the suction port will begin to open after the rotator has further rotated through another 180°. Thereafter, both the suction and discharge ports will remain open during the rotation of the rotor through another 180°. The opening and closing of the suction and discharge ports is reversible. That is, when the machine of this invention is to reverse its direction of rotation, the opening and closing of the suction and discharge ports may be effected in the same manner as aforementioned without recourse to the switching operation by means of a cam. Conventional machines can be adapted as reversible engines in the case of two cycle engines. However, such machines are low in scavenging efficiency which is one of the disadvantages of such machines. It is only after this invention has been made that the adaption of the machines of this type as four cycle reversible engines is made possible. In adapting this machine according to this invention as a reversible engine, it is required to arrange not only the electric ignition member or fuel injection members symmetrically on opposite sides of the position **65** but also the suction and discharge ports symmetrically with respect to the position **65**. As is clear in FIG. **9**, the explosion stroke takes place only during every other rotation of the rotor, so that it is necessary to rely on auxiliary energy supplied as by a flywheel for carrying on the rotation of the rotor when no explosion takes place. This problem can be obviated by arranging two machines in side-by-side relation as shown in FIG. **2** in which the opening and closing of the valves are adjusted such that explosion takes place at all times in one of the working chambers. This arrangement ensures that the machine operates smoothly and develops a high power.

Alternatively, three cylinders can be arranged in side-by-side relationship in which any one of the cylinders is in the explosion stroke at all times. If this is the case, every cylinder will be in the explosion stroke in every third revolution and a six cycle operation including suction, compression discharge, cooling (suction) and scavenging (discharge) will take place during the three revolutions. The provision of the cooling stroke is intended for increasing the efficiency of cooling and scavenging of the engine to obviate the problem of cooling of the parts in a high-speed and high-power engine wherein conventional air or water-cooling system or the cooling action of the lubricant can no longer serve the purpose.

In place of providing three parallel shafts for transmitting power as shown and described herein, more than three shafts disposed equiangularly relative to one another can be used. If a bearing portion is provided in the shaft of the rotor, one or two parallel shafts can be used for transmitting power.

FIG. **10** shows another embodiment of the machine of the rotary blade type according to this invention in which two parallel blade grooves **10***a* and **10***b* extend through the rotor **2** parallel to each other on opposite sides of the center axis of the rotor. One telescopic blade **6** is mounted for sliding motion in each of the blade grooves **10***a* and **10***b* the telescopic blade consisting of two-blade portions **6***a* and **6***b*, the solid plate-shaped blade portion **6***a* being telescopically movable into and out of U-shaped blade portion **6***b*. A blade-supporting shaft **36***a* is fixed to the free end of each plate-shaped blade portion **6***a* and a blade-supporting shaft **36***b* is fixed to the free end of each U-shaped blade member **6***b* as shown in FIG. **11**. Each of the shafts **36***a* is enclosed by a packing slider **7***a* rotatable about the shaft **36***a* and each of the shafts **36***b* is enclosed by a packing slider **7***b* rotatable about the shaft **36***b*. The adjacent pair of packing sliders **7***a* and **7***b* are formed with a mating recess and a projection respectively so that they are telescopically connected to each other. A plurality of axial grooves **31** are formed on the surfaces of the packing sliders **7***a* and **7***b* which are maintained in contact with the liner **64** mounted on the inner surface of the casing **1**. A packing band **32** is fitted in each of the axial grooves **31**. This arrangement provides a seal to the two working chambers. A and B to prevent the leaking of the working medium, in addition to forming an intermediate chamber C between the two working chambers A and B which is free from the working medium.

The arrangement in which the packing sliders **7***a*, **7***b* enclose the blade-supporting shafts **36***a*, **36***b* as aforementioned is conductive to the prevention of packing sliders **7***a*, **7***b* from pressing against the linear **64** on the inner surface of the casing **1** due to excess pressure applied thereto by centrifugal forces during the rotation of the rotor **2**. If the inner circumferential surface of the casing **1** is not cylindrical but concaved to increase the stroke volume as is the case with the embodiment of the machine shown on the right side of FIG. **12**, then the packing sliders **7***a* and **7***b* may be formed in a convex shape complementary with the concave shape of the inner surface of the casing.

In FIG. **12** are shown two forms of the machine of the rotary blade type according to this invention shown in FIG. **10** which are arranged in side-by-side relationship. This arrangement of FIG. **12** differs from the arrangement of FIG. **2** in that a shaft **33** is mounted to form an extension of the rotor **2**. The discal plates **8**, **8** used in this arrangement are each formed with two parallel cylindrical spaces **13** which are also parallel with the blade grooves **10***a* and **10***b* formed in the rotor **2**, and stepped grooves **60** and **61** for maintaining communication between the blade grooves **10***a* and **10***b* and the spaces **13**, **13** as shown in FIG. **13**. The stepped grooves **60** and **61** are each formed with axial wall portions **60***a*, **61***a* and wall portions **60***b*, **61***b* normal to the axial wall portions. The aforementioned U-shaped blade portions are received in these grooves for sliding motion. Each of the U-shaped blade portions **6***b* is guided by the wall portions **60***a* , **60***b* and **60***a*, **61***b* of the grooves **60** and **61** formed in the discal members **8**, **8** so that circumferential and axial forces are borne by these wall portions. The platelike blade portions **6***a* move in sliding motion into and out of the respective U-shaped blade portion members **6***b*. The cylindrical spaces **13**, **13** each have a slot **14** disposed alongside the respective cylindrical spaces to extend through the discal members **8**. The major dimension of the slots **14** corresponds to the range of movement of the platelike blade portions **6***a*. As shown in FIG. **12**, each of the discal members **8** is formed integrally with the ring-shaped portion **8'** in its outer periphery in the same manner as explained with reference to FIG. **2**. The

blade-supporting shafts 36*a* and 36*b* are fixed at their opposite ends to sliders 57*a* and 57*b* respectively which are adapted to move in sliding motion in the cylindrical spaces 13, 13 formed in the discal members 8. Secured to the sliders 57*a* and 57*b* respectively are shafts 39, 39 which are coaxial with the shafts 36*a* and 36*b* to form their extensions (FIGS. 12 and 14) and extend through the slots 14, 14 formed in the discal member 8. The shafts 39, 39 are supported by supporting portions 58*a* and 59*b* and 58*b* and 59*b* of supporting rotary members 5*a* and 5*b* respectively which are rotatably mounted in the casing 1 and concentric therewith (see FIG. 15). The sliders 57*a* secured to the supporting shafts 36*a* are larger in length than the sliders 57*b* secured to the supporting shafts 36*b*. The shafts 39, 39 which are disposed on one end of the two sets of blades 6, 6 are supported by the supporting portions 58*a*, 59*a* of one rotary member 5*a*, for example, and the shafts 39, 39 which are disposed on the other end of the two sets of blades 6, 6 are supported by the supporting portions 58*b*, 59*b* of the other rotary member 5*b*. The spacing between the two shafts 39, 39 supported by the same rotary member 5*a* (or 5*b*) is not constant but varies with respect to the circumferential direction of the rotary member. Thus, one of the shafts 39, 39 are received in a slot for movement therein. The shafts 36*a*, 36*b* and 39, 39 are intended to bring the forward ends of the blade portions 6*a*, 6 *a* and 6*b*, 6*b* in intimate contact with the inner surface of the working chamber in airtight relationship. As shown in the central portion of FIG. 12, only one rotary supporting member 5*b* is used for two sets of rotary supporting members 5*a*, 5*b* and 5*a*, 5*b*, which results in a simplification of the construction and a smaller length of the machine. The axially extending opposite side portions of the blade portions 6*b*, 6*b* are received in the stepped grooves 60, 60 and 61, 61 in the discal members 8, 8 formed integrally with the rotor 2 in such a manner that the blade portions 6*b*, 6*b* move in sliding motion while the lateral surfaces and end surfaces of the axially extending side portions of the blade portions 6*b*, 6*b* are maintained in airtight engagement with the axial wall portions 60*a*, 60*a* and 61*a*, 61*a* and circumferential wall portions 60*b*, 60*b* and 61*b*, 61*b* of the grooves 60, 60 and 61, 61 respectively.

Means is provided for avoiding a trouble which might be caused by the intercommunication between the working chambers and intermediate chamber through the grooves 60, 60 and 61, 61 and cylindrical spaces 13, 13 formed in the discal members 8, 8 (see FIG. 14). The sliders 57*a*, 57*a* and 57*b*, 57*b* to which the blade-supporting shafts 36*a*, 36*a* and 36*b*, 36*b* are secured are each formed with a sliding portion 45 which is adapted to move in sliding motion in each of the stepped grooves 60, 60 and 61, 61 while maintained in sealing contact therewith. The sliding portion 45 comprises a portion 45*a* which is adapted to move in the narrow portion of the grooves and a portion 45*b* which is adapted to move in the wider portion of the grooves, the portion 45*a* being of the same length as the slider 57*a* or 57*b* and the portion 45*b* having a smaller length than the portion 45*a*. The sliders 57*a*, 57*a* and sliding portions 45*a*, 45*a* associated with the solid blade portions 6*a*, 6*a* have a length such that they can prevent intercommunication between the working chambers A and B and intermediate chamber C through the cylindrical spaces 13, 13 and grooves 60, 60 and 61, 61 even when the blade portions 6*a*, 6*a* are entirely out of the respective blade portions 6*b*, 6*b* so that the blades 6, 6 have reached their maximum length. From the foregoing description, it will be appreciated that the machine of the rotary blade type according to this invention can have a markedly large compression ratio relative to the eccentricity of the rotor. Stated differently, the machine permits to provide a provide a predetermined compression ratio even if the rotor has a relatively large diameter. This facilitates designing of the machine because the use of a rotor of large diameter is conducive to increased strength of the rotor. Another feature of the machine according to this invention is the provision of the packing sliders 7*a* and 7*b* which are telescopically interconnected for providing a seal to the intermediate chamber C against the working medium. Since the intermediate chamber C can be made free from the working medium, it is possible to introduce a cooling medium thereinto through passageways formed in the rotor and its rotary shaft, thereby effectively cooling the machine particularly when it is adapted as an internal combustion engine in which cooling poses a problem.

What I claim is:

1. A machine of the rotary blade type comprising a casing;

a rotor rotatably mounted in said casing and disposed eccentrically with respect to the cylindrical inner surface of the casing; at least one telescopic blade mounted for sliding motion in a blade groove formed to extend through said rotor, said telescopic blade comprising a plurality of blade portions telescopically fitted one into another; discal members fixedly mounted on opposite end surface of said rotor and formed with grooves for supporting and guiding said telescopic blades, said casing, said rotor, said discal members and said telescopic blades defining working chambers which undergoes a change in capacity as said rotor rotates; and support means arranged in two rows on the outsides of said discal members for positioning respective blade portions, said support means being parallel to each other and mounted rotatable and concentrically with the cylindrical inner surface of the casing through antifriction means.

2. A machine of the rotary blade type as claimed in claim 1, characterized in that said telescopic blades are two in number and disposed for sliding motion in two parallel blade grooves formed to extend through said rotor, said two blades defining therebetween an intermediate chamber which is sealed against the working medium.

3. A machine of the rotary blade type as claimed in claim 1 characterized in that a gear and a positioning annular groove are provided on the outer peripheral surface of each of said discal members, and a plurality of shafts are provided parallel to the rotor axis for mounting thereon a gear and friction wheel which are adapted to mesh with said gear and said groove on the outer peripheral surface of each discal member for transmitting power through said shafts.

4. A machine of the rotary blade type as claimed in claim 1, characterized in that said rotor is disposed eccentrically with respect to the casing such that the working medium can be prevented from leaking through a position in which the rotor is brought into contact with the inner surface of the casing, and a recess is formed between the blades on the surface of the rotor for allowing the working medium to pass therethrough.

5. A machine of the rotary blade type as claimed in claim 1, characterized in that ring-shaped airtight rotors are rotatably mounted concentrically with the cylindrical inner surface of the casing and maintained in contact therewith through antifriction means, said airtight rotors being disposed on the lateral sides of the discal members in face-to-face relationship, said airtight rotors being maintained in intimate contact with the tips of the blades or sliders provided on the tips of the blades.

6. A machine of the rotary blades type as claimed in claim 1, characterized in that means is provided for adjusting the opening and closing of suction and discharge valves and the timing of ignition of electric ignition means or of fuel injection of fuel injection means, whereby the machine can be adapted to perform a four cycle operation or six cycle operation including the cooling cycle and scavenging cycle.

7. A machine of the rotary blade type as claimed in claim 6, characterized in that two ignition means or two fuel injection means and suction and discharge valves are mounted symmetrically on opposite sides of the contact position of the rotor and the inner surface of casing, whereby the machine can be made self-reversing.

8. A machine of the rotary blade type as claimed in claim 1, characterized in that two machines are arranged in side-by-side relationship, each of said machines performing a four cycle operation such that one of the working chambers of the

two machines are in the explosion cycle for each one of the four cycles.

9. A machine of the rotary blade type as claimed in claim 1, characterized in that three machines are arranged in side-by-side relationship, each of said machines performing a six cycle operation including the cooling cycle and scavenging cycle such that one of the working chambers of the three machines are in the explosion cycle for each one of the six cycles.

10. A machine of the rotary blade type as claimed in claim 2, characterized in that packing sliders mounted on the tips of the two parallel blades are telescopically connected together so as to thereby provide a seal to each of the working chambers and the intermediate chamber.

11. A machine of the rotary blade type as claimed in claim 2, characterized in that a cooling medium is introduced into said intermediate chamber.