# United States Patent [19]

**Jeandel**

[11] **3,810,722**

[45] **May 14, 1974**


[54] **ENGINES AND COMPRESSORS OF THE KIND IN WHICH A VALVE DEVICE ENGAGES WITH A HELICOIDAL ROTOR**


[76] Inventor: **Ferdinand Jeandel,** 39 rue Roussin-75, XVI Paris, France



[22] Filed: **Dec. 22, 1971**

[21] Appl. No.: **210,710**

[30] **Foreign Application Priority Data**

Dec. 16, 1970 France .............................. 70.45340
Nov. 29, 1971 France .............................. 71.42621

[52] **U.S. Cl.** ................................ **418/195,** 60/39.45
[51] **Int. Cl.** ............................ **F01c 3/02,** F02c 7/00
[58] **Field of Search** ............ 60/39.45; 418/195, 197



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*Assistant Examiner*—Michael Koczo, Jr.
*Attorney, Agent, or Firm*—Robert E. Burns; Emmanuel J. Lobato



[57] **ABSTRACT**

The invention relates to a rotary machine which can be used as a motor, a compressor or a motor-compressor or the like. The machine comprises a first and a second body of revolution, one of which is stationary, the other rotating, and at least one helicoidal-spiral groove in the surface of the first body, and at least one valve device with peripheral vanes. The valve device rotates in a longitudinal plane of symmetry of the first body, the vanes engaging in the groove in the first body, the wall of the second body cooperating with the vanes to limit successive chambers of variable volume which change the pressure in a fluid. One of the bodies has at least one part in the form of a projection, also in the form of a body of revolution, the other body having at least one wall part, situated opposite the projection and having a shape complementary to the projection, there being very little clearance between these parts. The shapes of these projecting parts are adapted to modify the flow of fluid through the machine so as to make it agree with the method of functioning of the machine.


**10 Claims, 33 Drawing Figures**

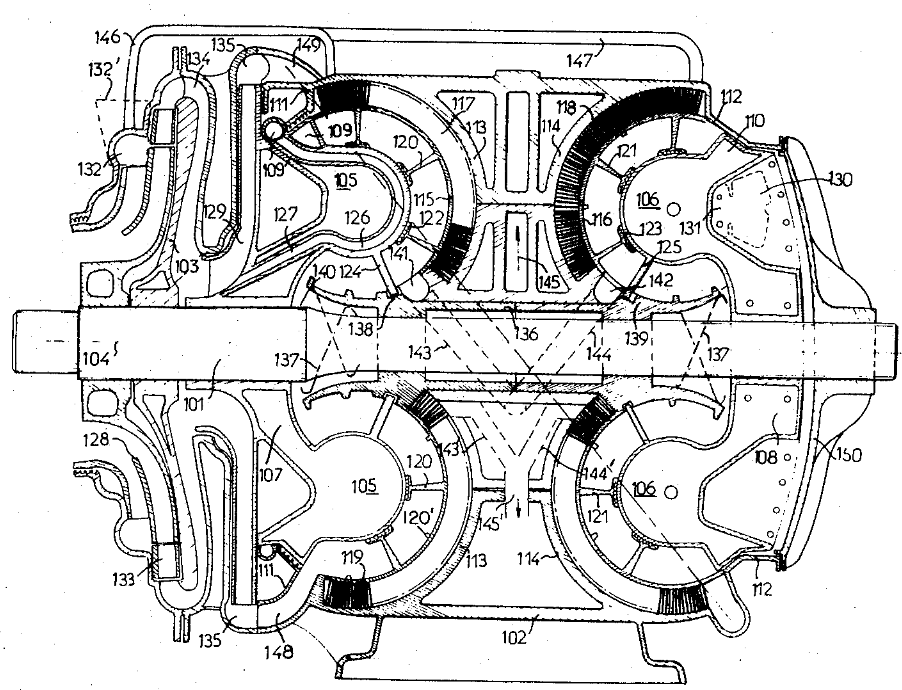

FIG.2

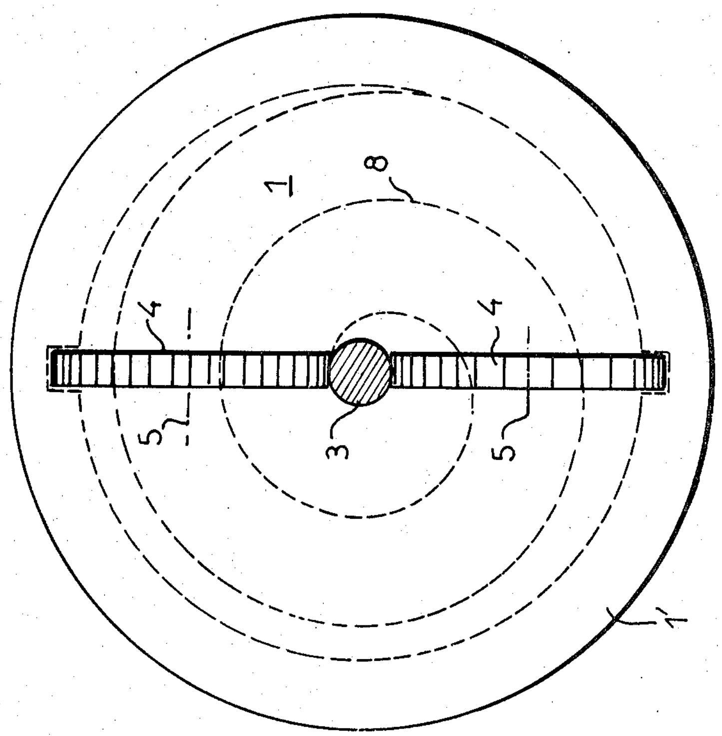


FIG.1

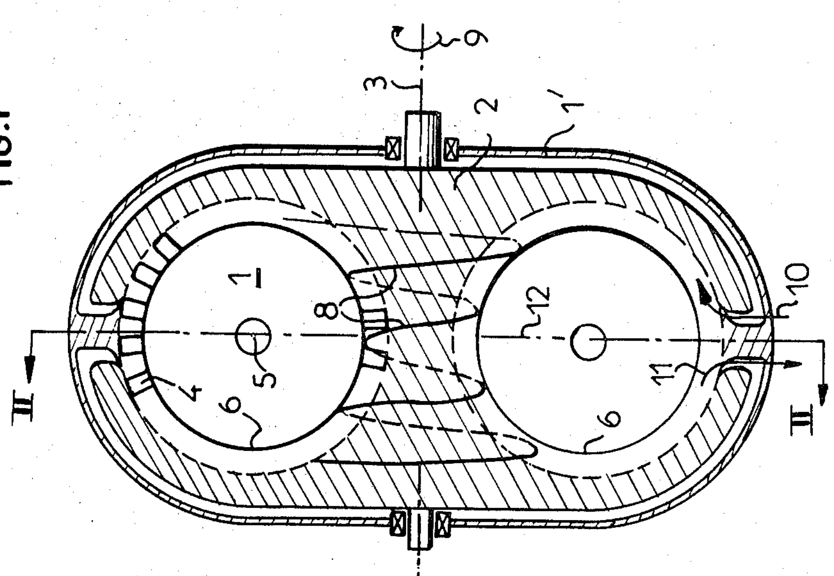

FIG.3

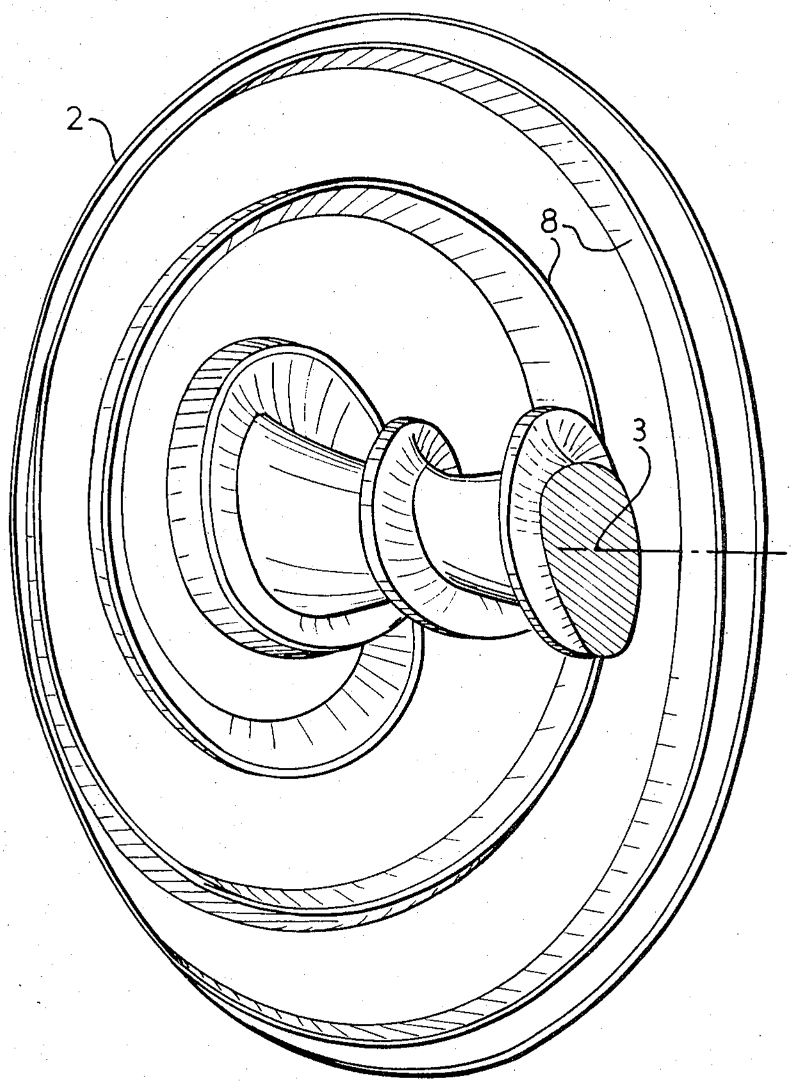

FIG.4

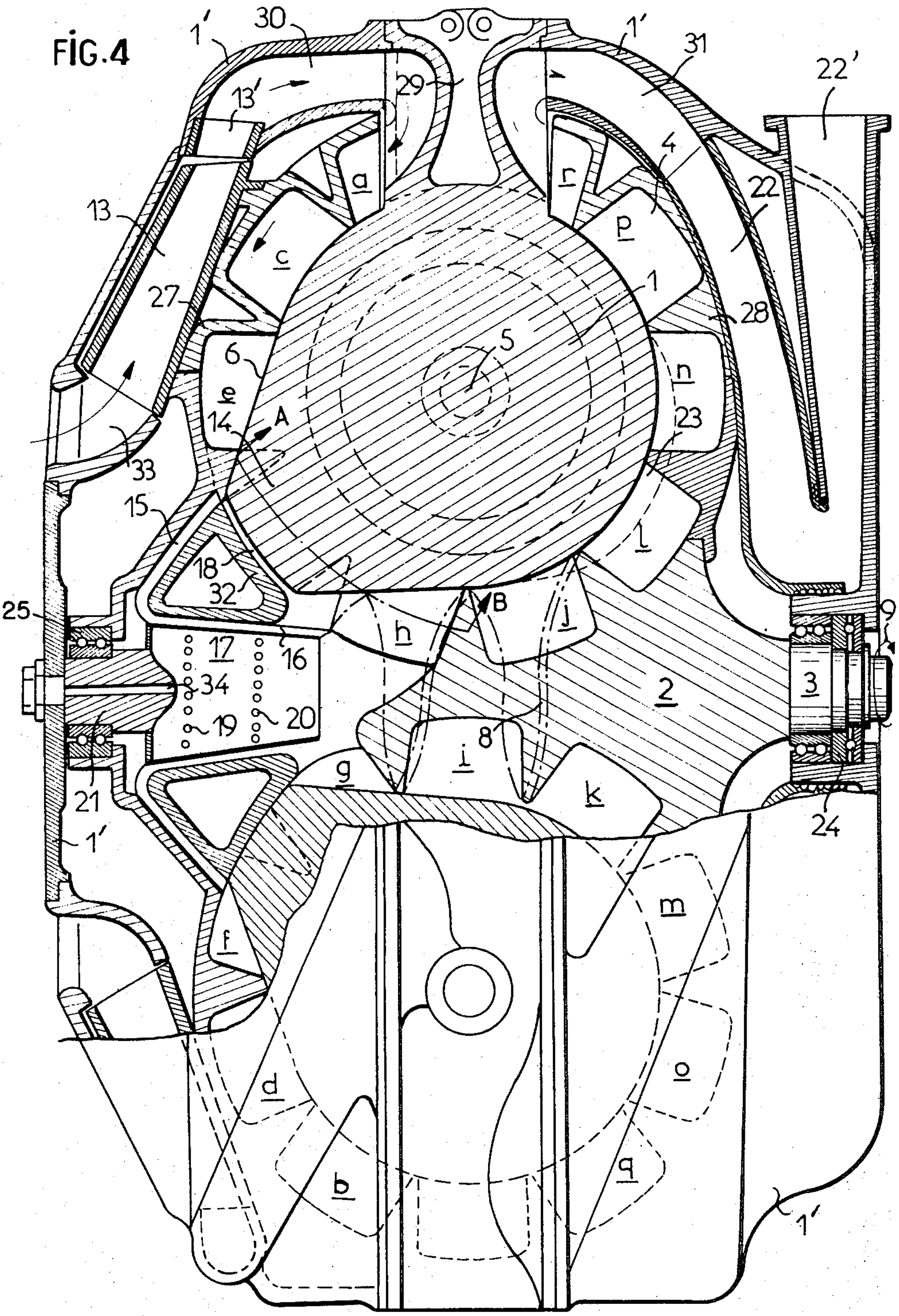
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FIG.5

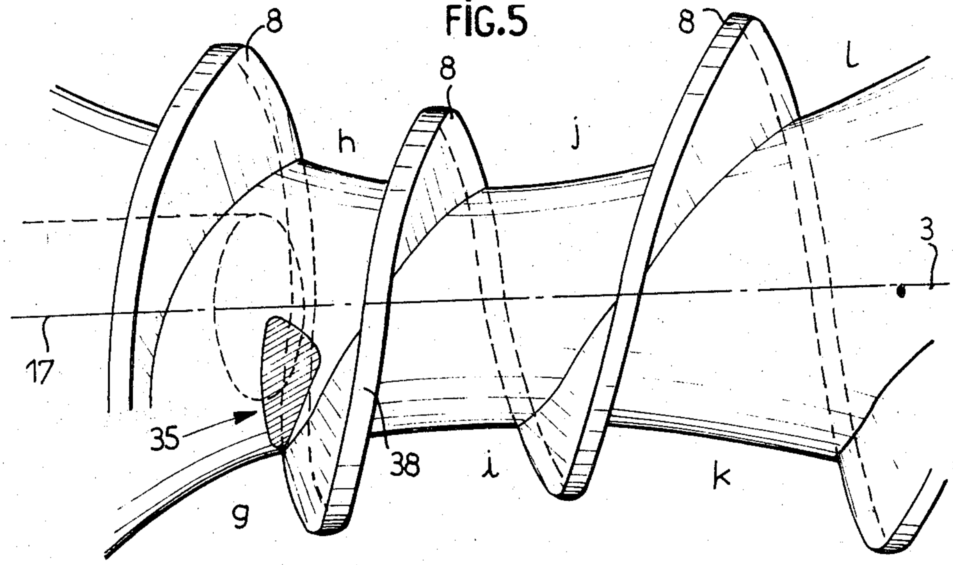



FIG.6

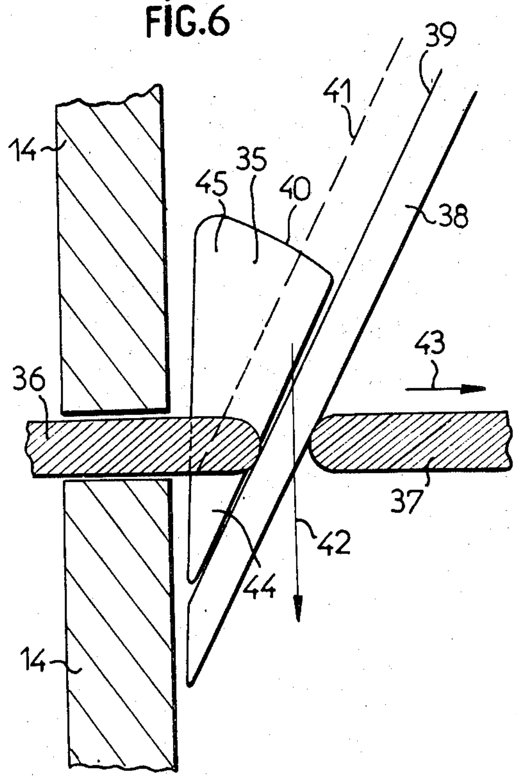



FIG.7

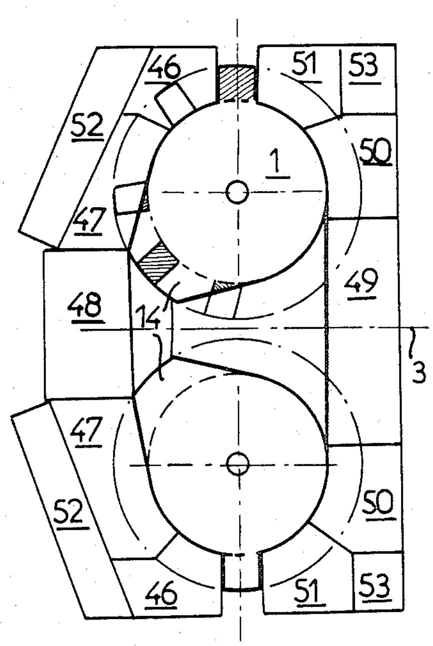


FIG.8

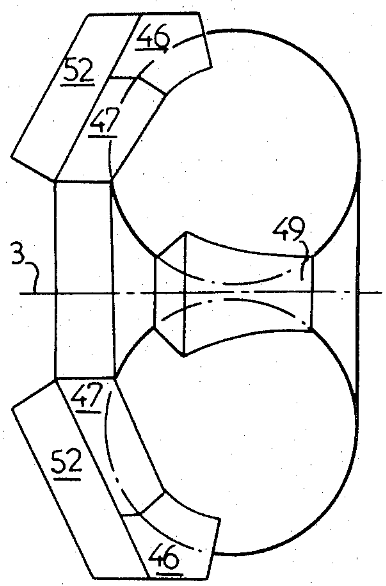



FIG.9

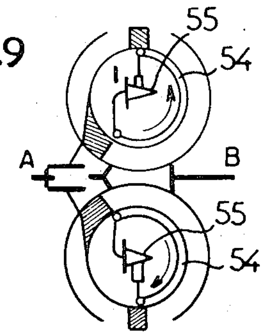



FIG.10

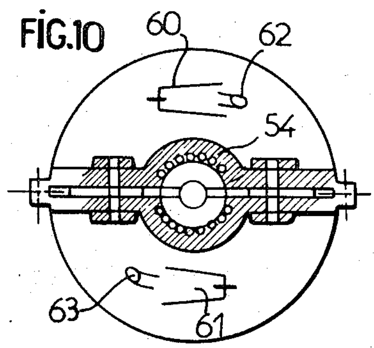



FIG.11

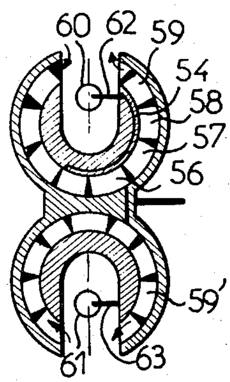



FIG.12

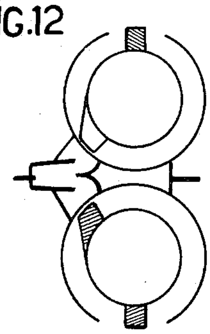


FIG.13

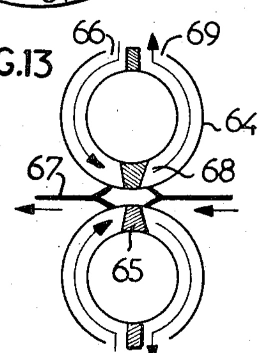



FIG.14

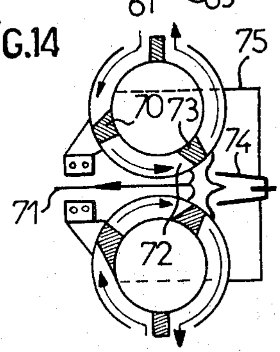



FIG.15

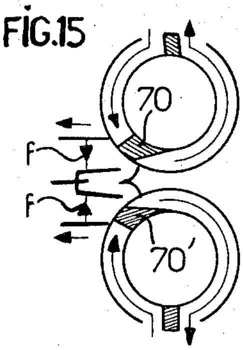



FIG.16

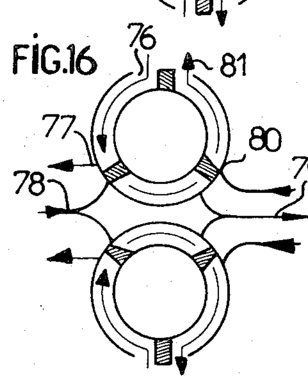


FIG.17

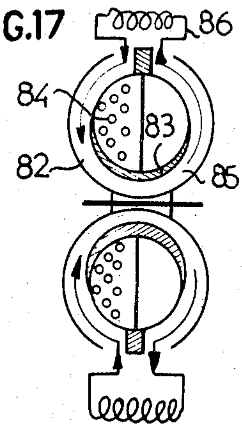



FIG.18

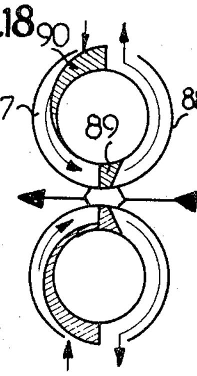



FIG.19

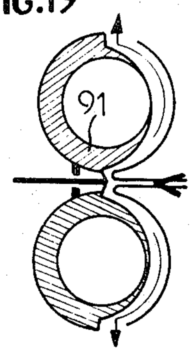



FIG.20

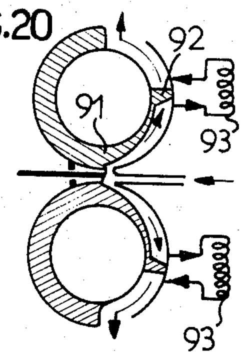



FIG.21

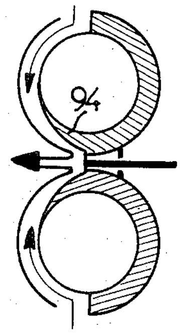



FIG.22

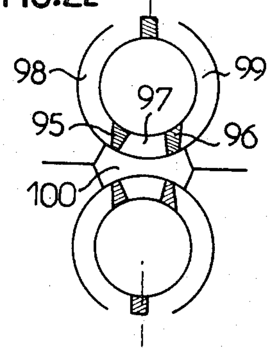



FIG.24

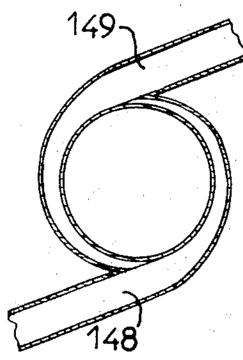
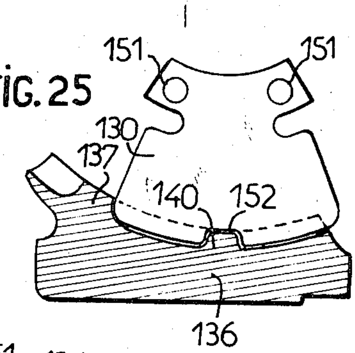



FIG. 25

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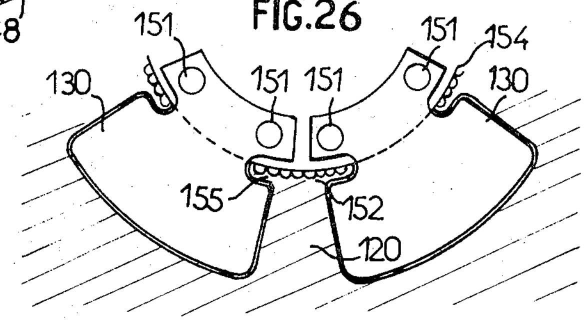

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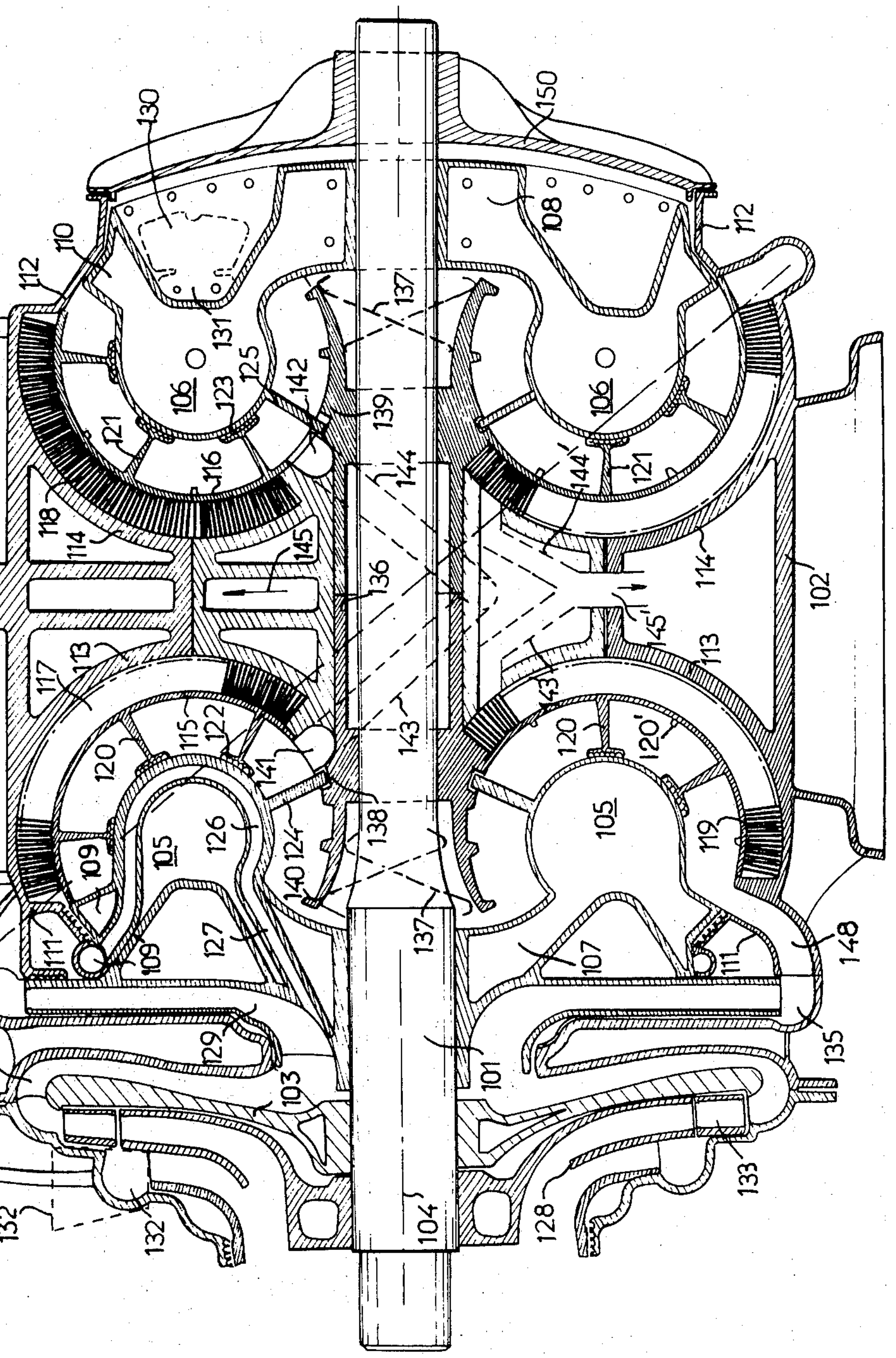
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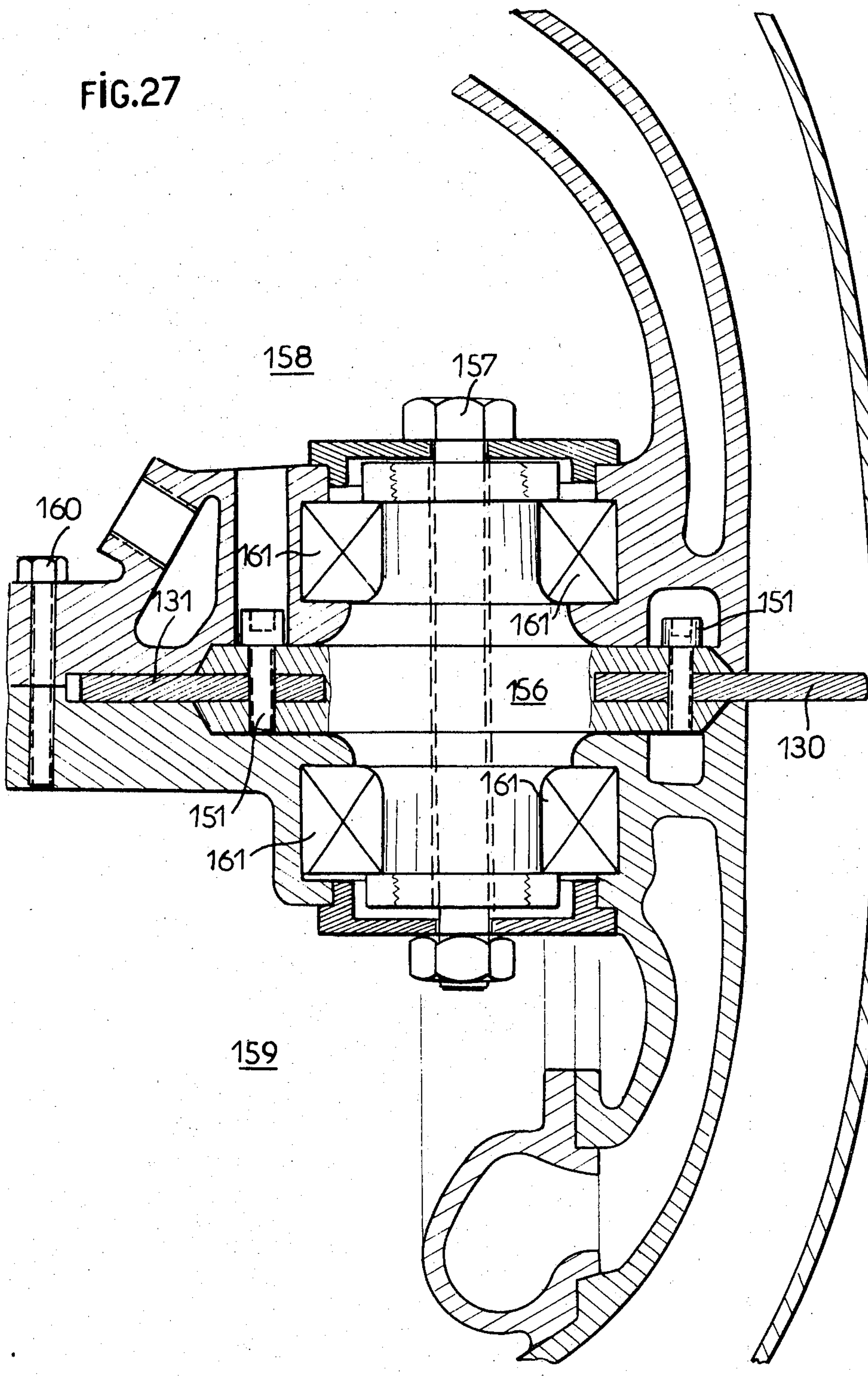
FIG.27



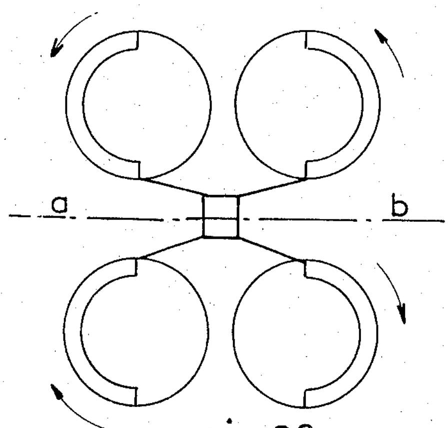



FIG.28

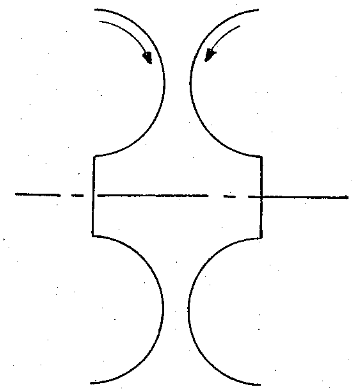


FIG.29

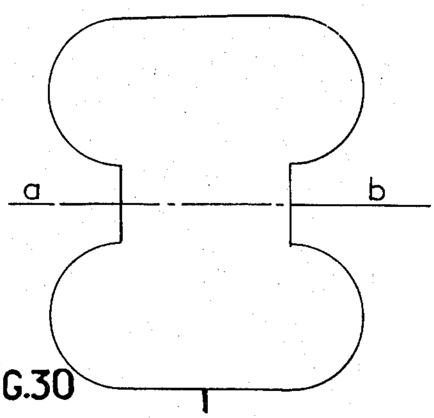



FIG.30

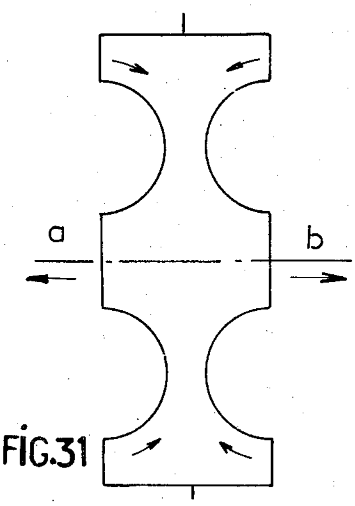



FIG.31

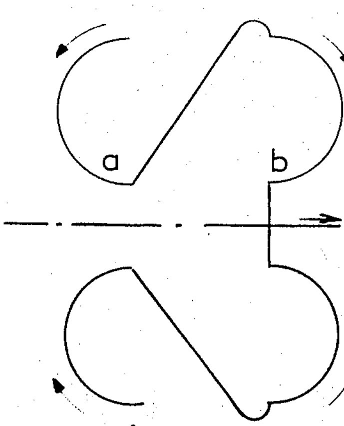



FIG.32

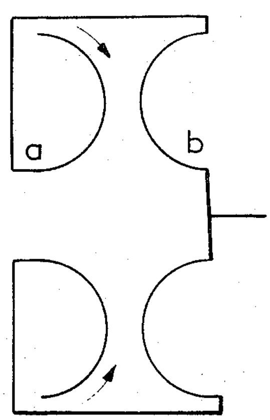



FIG.33

# ENGINES AND COMPRESSORS OF THE KIND IN WHICH A VALVE DEVICE ENGAGES WITH A HELICOIDAL ROTOR

The present invention relates to rotary machines of the kind which can be used as a motor or as a compressor or as a motor-compressor, a machine of this kind having a rotor which rotates inside a stator, in which a fluid is successively compressed and decompressed in chambers of decreasing and increasing volume, each chamber being limited by the walls of at least one helicoidal groove in the surface of the rotor, by the surface of the stator and by the surface of at least one valve device with peripheral vanes which engage in the helicoidal groove, the valve device rotating in a longitudinal plane of symmetry of the rotor, the object of the invention being in particular to improve the performance of a machine of this kind, particularly its efficiency and the power delivered, so as to make the machine suitable for a wider variety of applications, compared to the known machines of this kind, and so as to reduce the weight of the machine and its cost of construction.

Machines of this kind are known in which a gas is compressed in a chamber of decreasing volume limited by the surface of an internal stator in the form of a solid torus, by the walls of a helicoidal groove in the surface of a rotor, which completely encloses the internal stator except where the periphery of the stator is joined to an external housing, and by at least one rotary valve device which has projecting vanes which engage in the helicoidal groove. The known device, which is represented diagrammatically in FIGS. **1, 2** and **3,** consists essentially of a rotor **2** which rotates about an axis **3** in the direction of the arrow **9.** The rotor **2** contains a helicoidal groove between ribs **8** in which engage with close clearances the vanes of two valve devices **4.** Each valve device **4** rotates on an axis **5** which extends perpendicular to the axis **3** of the rotor in the longitudinal central plane of symmetry of the latter. The two valve devices **4,** in the form of wheels with peripheral vane blades, rotate in a common vertical plane, between the two symmetrical halves of an internal stator **1** in the form of a solid torus. All these parts are contained in a stationary external housing **1'.** The internal toroidal stator is attached to the outer housing **1'** by an annular bridge which is in the transverse plane of symmetry of the internal stator **1.** The vanes **4** project radially outwards beyond the surface **6** of the stator. As already mentioned, the vanes **4** engage in the helicoidal groove of the rotor. FIG. **2** is a transverse section of the machine, taken along the line **II — II** in FIG. **1.** Regarded from this direction the projection of the rib **8** assumes the form of a spiral. FIG. **3** is a 3-dimensional representation of the inside of one half of the rotor, showing a helicoidal rib **8.**

Assuming that the rotor is rotating, as indicated by the arrow **9** in FIG. **1,** the gas enters through an inlet port **10,** entering a helicoidal chamber limited by the first rib **8** of the helicoidal groove in the surface of the rotor **2,** by the surface **6** of the solid torus which forms the stator **1,** by a vane of the upper valve device and a vane of the lower valve device.

With rotation of the rotor, the stator vanes follow the helicoidal groove in the rotor, progressively reducing the volume of the helicoidal chamber, which is least in the middle region of the device at **12.** During this movement the gas in the helicoidal chamber is compressed. In the subsequent phase of the process the gas expands, on its way from the middle region **12** to the outlet port **11.** In the case of an internal combustion engine, the combustible mixture entering the engine through the inlet port **10** is compressed, reaching maximal compression at the middle region **12,** where it is ignited, subsequently expanding on its way from the middle region **12** to the outlet port **11,** this being the working stroke of the engine. On the other hand, if the device is merely a compressor, the device is limited to the part between **10** and **12.**

This known device is already approaching the efficiency and power of a conventional motor or compressor. It can be used in the form of an internal combustion engine or a Diesel cycle engine. It can be arranged as a multistage motor comprising several compression stages and several expansion stages, arranged in series or in parallel. Nevertheless the known device has several disadvantages. In particular the power to weight ratio and the thermal efficiency are comparatively low, limiting the field of application. Furthermore the device tends to heat up locally, particularly in the region of the combustion chamber, if the device is in the form of an internal combustion engine with the combustion chamber incorporated in the rotor. The local overheating requires excessive clearances to be provided between the parts of the rotor and the parts of the stator.

The object of the present invention is to remove these disadvantages by modifying and rearranging the parts of the rotor and of the stator, at the same time taking steps to increase the power to weight ratio and the thermal efficiency of the device.

The machine according to the invention is characterised in that the stator (or the rotor) has at least one projecting body of rotation, the rotor (or the stator) having a corresponding annular recess, there being a very small clearance between the surface of the projection and the surface of the recess, the projection and the recess being arranged so as to modify the flow of the gas through the machine to agree better with the method of functioning of the machine.

The invention will now be described on the basis of the several examples represented in the drawing, in which:

FIGS. **1** and **2,** which have been mentioned above, represent diagrammatically an internal combustion engine according to the invention.

FIG. **3** is a 3-dimensional view of one half of the rotor of the known device represented in FIGS. **1** and **2.**

FIG. **4** is an axial section through one version of a machine according to the invention, in the form of an internal combustion engine.

FIGS. **5** and **6** illustrate diagrammatically the path taken by the burnt gases from the combustion chamber into the helicoidal groove in the rotor of the machine of FIG. **4.**

FIG. **7** is a diagrammatical representation of the machine of FIG. **4.**

FIG. **8** represents diagrammatically a machine according to the invention arranged to function as a compressor.

FIGS. **9, 10** and **11** represent another version of the machine of FIG. **4.**

FIGS. 12,13,14,15,16,17,18,19,20,21 and 22 represent diagrammatically several other versions of the machine according to the invention.

FIG. 23 is a still further version of the machine according to the invention.

FIG. 24 is a detail of the volute surrounding the supercharger of the machine of FIG. 23.

FIG. 25 shows, drawn to a larger scale, a vane of a valve device in the machine of FIG. 23.

FIG. 26 shows in somewhat more detail two vanes of a valve device engaged in the helicoidal grooves, showing in cross section the rib between the grooves.

FIG. 27 is a section through the axis of the valve device in the machine of FIG. 23.

FIGS. 28 to 33 show very diagrammatically several different ways of joining the two parts of the machine together.

With reference to FIG. 4, this shows a preferred version of the rotary machine according to the invention, in the form of an internal combustion engine equipped with a centrifugal precompressor for the entering gas and a device for recovering the residual energy in the exhaust gases. The machine consists of a rotor 2 whose surface contains a helicoidal groove, the rotor rotating about an axis 3 in the direction of the arrow 9. The rotor shaft rotates in bearings 24,25 in a stationary outer housing 1'. The rotor has outer parts 27,28 which completely enclose an internal stator 1, except where the stator is joined by a peripheral bridge connection 29 to the outer housing 1'. The two outer parts 27,28 contain between them symmetrically a hollow torus which has a peripheral gap on its transverse plane of symmetry, to give room for the bridge connection 29. The stator 1 is a body of revolution whose axis is the axis of the rotor 2. The concave inner surface of the rotor contains a helicoidal-spiral groove, some of whose side ribs 8 are at least partly cut away, as will be described further below. The helicoidal-spiral groove in the two outer parts 27 and 28 is a precise continuation of the helicoidal groove in the central part of the rotor, so that the inner surface of the rotor, which faces the outer surface 6 of the stator 1, contains a continuous helicoidal groove for guiding the flowing gases. In the known device the internal stator 1 consisted of two solid half-toruses containing between them the two valve devices 4, each of which was mounted to rotate on an axis 5. In the improved machine according to the present invention, on the other hand, the internal stator is in the form of a solid torus which has a projecting part 14, in the form of a body of revolution, the part 14 being of one piece with the solid torus proper. The rotor 2 has an annular recess 32 corresponding to the annular projection 14 on the stator, so that only a very small clearance 18 remains between these two parts. The cross section of the annular projection 14 is such that it completely covers at least one vane of the rotary valve device, as shown in FIGS. 4 and 7. Consequently the ribs 8 of the helicoidal groove in the rotor are entirely removed in the region of the projection 14, and are partly removed on either side of this region. The helicoidal groove is subdivided by the vanes 4 of the valve device into a number of chambers of successively decreasing volume *a, b, c, d, e, f,* and a number of chambers of successively increasing volume *g, h, i, j, k, l, m, n, o, p, q, r.*

The other end of the rotor 2, that is to say the end of the rotor which has the outer part 27, contains a central chamber 16, which itself contains a combustion chamber 17, a certain amount of clearance remaining between the combustion chamber 17 and the wall of the chamber 16. The combustion chamber 17 is fixed to the outer housing 1' of the machine. The outer housing 1' also contains a centrifugal turbine 13 and a centripetal turbine 22. The rotor of the turbine 13 is fixed to the outer part 27 of the rotor 2, rotating with the latter about the axis 3, inside the outer housing 1'. The centripetal turbine 22 is situated on the opposite side of the machine, compared to the centrifugal turbine 13, that is to say on the opposite side of the transverse plane of the stator 1 and rotor 2. The rotating part of the centripetal turbine 22 is of one piece with the outer part 28 of the rotor 2.

When the motor is in operation, the fluid, for example the combustible mixture, enters the engine through an inlet port 33 in the outer housing 1', as shown by the arrow. The fluid is aspirated by the centrifugal turbine 13, which applies a precompression. Leaving the turbine 13 the air or combustible mixture passes through a diffuser 13', just downstream of the turbine, and through passages 30 in the outer housing 1', and through a peripheral connecting passage 29 into the helicoidal groove of the rotor. In the helicoidal groove the fluid is trapped by the vanes of the two valve devices in chambers *a, b . . . f,* in which it is progressively compressed. From the chambers e and f the compressed fluid escapes through branch channels 15 and so enters the central chamber 16 which contains the combustion chamber 17. Little or no fluid can escape through the very narrow clearance 18 between the parts 14 and 32. The compressed fluid entering the chamber 16 forms a layer of moving gas around the combustion chamber 17. After entering the chamber 16 the fluid penetrates inwards through a series of openings 19,20 into the interior of the combustion chamber 17. The combustion chamber is of one piece with a connecting stud 21 fixed to the outer housing 1'. In a different version of the invention the combustion chamber is of one piece with the rotor 2. In the present version the connecting stud 21 contains one or more fuel burners 34.

If desired the amount of clearance 18 between the projection 14 of the stator and the surface of the recess 32 in the rotor can be great enough to allow a certain amount of air to pass through, to act as secondary air, in order to limit the temperature of the impinging burner flame downstream of the combustion chamber 17.

The burnt gases leaving the combustion chamber enter successively the chambers *g, h, i, j, k, l, m, n, o, p, q, r,* in which they expand, finally issuing through the exhaust channel 31. From here the exhaust gases pass through the centripetal turbine 22 in which residual energy is recovered. From the centripetal turbine the exhaust gases issue through a volute 22' situated near the rotor.

In a different version of the invention the toroidal stator 1 has a further convex projection 23, shown in broken lines in FIG. 4. To conform with this projection the ribs 8 of the rotor 2 are partly cut off. The function of the projection 23 is to modify the pressure curve during the working stroke, particularly with a view to producing a smooth pressure curve. In particular it is desirable to balance the pressures acting on the vanes of the valve device. The projection 14, which reduces or entirely covers the surfaces of some of the vanes, gives rise to unbalanced forces acting on the valve device. The second projection 23 reduces this disequilibrium, in addition to influencing the pressure curve during the working stroke.

FIG. 5 is a diagrammatic 3-dimensional view of the rotor 2. FIG. 6 is a section taken along the line A-B in FIG. 4. The path taken by the burnt gases passing from the combustion chamber 17 into the first helicoidal expansion chamber will now be described, with the help of these two figures. From the combustion chamber 17 the burnt gases pass through a port 35 in the bottom of the groove in the rotor, between the first two ribs 8 downstream of the combustion chamber. The port 35 is approximately triangular and has walls curved to allow the burning gases to pass smoothly through without abrupt expansion. Abrupt expansion would reduce the efficiency of the engine. In FIG. 6 two neighbouring vanes of a valve device 5 are shown at 36 and 37, the two vanes enclosing between them a rib 38 which is the first of the ribs 8 situated downstream of the combustion chamber 17. The leading edge of the rib, with reference to the direction of rotation of the rotor, is indicated at 40. The port 35 has its mouth at the base of the rib 38. The direction of rotation of the rotor is indicated by the arrow 42. The direction of rotation of the valve device is indicated by the arrow 43. The rib 38 and the port 35 are shown in the intermediate positions they occupy when burnt gases are flowing into the two helicoidal chambers g and h, on either side of the vane 36. With the rib 38 in the position shown, the burnt gases enter the helicoidal chambers 44 and 45, the chamber 44 being limited by the surface 39 of the rib, the vane 36 and the part 14 of the stator. On the other hand, when the edge 39 of the rib 38 is in the position 41 represented by the broken line, no gases can enter the helicoidal chamber 44. With rotation of the rotor in the direction of the arrow 42, gases increasingly enter the chamber 44, the flow of gases into the chamber 45 decreasing, until the trailing edge 40 of the port 35 reaches the vane 36. In order to prevent an abrupt shut off of the gas flow, which would produce an impact effect, the trailing edge 40 of the port 35 forms an angle with the plane of the valve device. This produces a gradual shutting of the port.

FIG. 7 represents diagrammatically the machine of FIG. 4, to indicate in a general way the different parts of the rotor. The rotor consists of several parts assembled coaxially to facilitate machining operations and the assembling and dismantling of the rotor, and so as to allow the best material of construction to be used for each part. Two parts 46 and 47 serve for volumetric compression. One part 48 is for deflecting the compressed fluid towards the combustion chamber. The three parts 49,50,51 are for expansion of the burnt gas. Upstream of the part 46, where the first compression takes place, there is a part 52 which serves for centrifugal precompression. Downstream of the part 52, in which the last expansion takes place, there is a second turbine 53 for recovery of residual energy.

FIG. 8 represents diagrammatically a machine according to the invention intended for use as a compressor. Some of its parts correspond to parts in FIG. 7, but the parts 50, 51, 53 are missing in FIG. 8, and the part 49 necessarily has a different shape.

In another version of the invention, represented in FIGS. 9, 10 and 11, the device contains a bundle of contiguous tubes through which water circulates, for limiting the temperature in the region of the chambers g and h (compare FIG. 4), and two afterburner chambers for improving the thermal efficiency FIG. 9 is a diagrammatical representation of the machine shown in FIG. 4. FIG. 11 is an axial section taken along the line A-B in FIG. 9. FIG. 10 is an end view of the machine of FIG. 9. The stator 1 contains a bundle of contiguous tubes 54 arranged as a layer near the surface of the stator and in contact with the expansion chambers 56, 57, 58, 59. The water circulates in the directions of the arrows, propelled by pumps 55 which are driven by the axles of the valve devices. This arrangement has the result that the heat removed from the combustion gases in the region of the first expansion chambers just downstream of the combustion chamber is transferred to the region of the chambers further downstream, reheating the expanding gases. Furthermore, there are two afterburner chambers at the locations 60 and 61, the burnt gases passing into the chambers 59 and 59′ through elbow ducts 62 and 63. The two chambers 59 and 59′ are for example the stages *n,o,p,q* of the machine of FIG. 4. Fuel is fed in at the center of the machine, air being bled off from the region of highest compression and fed into the two combustion chambers 59 and 59′.

FIGS. 12 to 23 show diagrammatically various other versions of the machine according to the invention, each figure being a vertical axial section. In these greatly simplified figures the projections on the stator 1 are represented in section by hatched areas in the drawings.

FIG. 12 represents a motor, essentially similar to the motor of FIG. 4, but in which the compressed gases are deflected only partly towards the combustion chamber, that is to say there is a considerable gap 18 between the parts 14 and 32 in FIG. 4, so that a considerable flow of secondary air passes between these parts.

FIG. 13 shows a compressor driven by a positive displacement steam engine 64. The steam engine occupies one half of the device, the other half being the compressor. The hatched areas 65 are projections of the stator, arranged to act as separating walls between the two halves of the machine. The air is sucked in at 66, the compressed air being ejected through 67. The steam passes in at 68 and is exhausted at 69.

FIG. 14 represents diagrammatically an internal combustion motor-compressor in which the air is cooled during compression. A deflector 70 deflects the air through an external cooling circuit 71, from which the air returns and flows again through the part of the machine downstream of the deflector 70, as represented by the arrows. Finally the air is deflected by a deflector 73, which acts as a separating wall between the compressor and the motor parts of the device. Final compression takes place in the region 72. The combustion chamber is shown at 74, for the motor half of the device, the feed of compressed air being indicated at 75.

FIG. 15 shows diagrammatically a motor-compressor which has no cooling arrangements. The air is compressed progressively until it is totally deflected by a deflector 70. Part of the air is bled off and fed to the combustion chamber for the motor half of the machine. The bled off air is fed to the combustion chamber as indicated by the arrows f. The burnt mixture enters the central part of the machine and expands to give the working stroke.

The device in FIG. **16** is a motor-compressor which allows two different fluids to be compressed simultaneously. The part of the device between **80** and **81** is a steam engine, the steam entering at **80** and escaping at **81.** A first fluid enters at **76** and, after progressive compression, escapes at **77,** where it is totally deflected, as already described above.

A second fluid enters at **78,** entering between the stator and the rotor at the other side of the deflector **78.** After compression this fluid escapes at **79,** being totally deflected by a deflector arranged between this compressor and the steam engine part of the device.

FIG. **17** is a refrigerating machine driven by an external motor which is not shown in the drawing. The cold-producing fluid is compressed at **82** and expands at **85.** A projection **83** of the stator is interposed between the compression zone and the expansion zone, the projection **83** reducing the cross sections of the chambers formed by the stator and the walls of the helicoidal groove in the rotor, the rotor ribs being partly cut off to give room for the projection **83.** A cooler is indicated at **84,** for cooling the cold-producing fluid. The cooling circuit of the refrigerant fluid is indicated at **86.**

FIG. **18** represents the principle of a steam driven motor-pump in which the pump part **87** is completely separated from the motor part **88.** The separating wall **89** is in the form of a projecting part of the stator, the projection **89** coming flush with the inner wall of the rotor with practically no clearance. Steam enters the circuit **88** downstream of the projection **89,** which retains the steam entirely in the motor circuit **88.** The fluid which is being pumped enters the circuit **87** near the periphery of the machine. The pumping chambers retain the same volumes, due to a projection **90** (shown hatched) of the stator, assuming that the fluid is incompressible.

FIGS. **19** and **20** represent steam engines with and without superheating. In FIG. **19** the steam flows through the machine in the directions of the arrows. The steam enters chambers of increasing volume between the rotor and the stator, this effect being produced by a projection **91** of the stator, which completely blocks the lefthand part of the machine, as shown in the figure. The projection **91** reduces the volumes of the chambers near the steam outlet. In FIG. **20** a superheater **93** is provided. The steam is deflected entirely into the superheater **93** by a projection **92** of the stator, as indicated by the arrows. After passing through the superheater the steam reenters the circuit downstream of the deflector **92,** to pass through the last expansion chambers before escaping.

The device shown in FIG. **21** is a compressor which gives a high degree of compression. The fluid, flowing in the direction of the arrow, is progressively compressed, the compressive effect being increased by a projection **94,** which entirely blocks the righthand side of the machine, the projection **94** also acting as a deflector which compels the highly compressed fluid to leave the machine through the delivery duct indicated at the left in the figure.

FIG. **22** is a variant of the device shown in FIG. **13.** In this case there are two deflectors **95** and **96** in place of the single deflector **65** in FIG. **13.** The deflectors **95** and **96** are total deflectors in the form of projections of the stator. Between the two deflectors **95** and **96** there is a chamber **97** which surrounds the central part **100** of the rotor, the chamber **97** being entirely separated from the circuits **98** and **99** of the machine. The chamber **97** is arranged so that it can accommodate a mechanism for driving the rotary valve devices, which are not shown in the figure.



FIG. **23** shows a further advantageous version of the invention, this arrangement providing a considerable improvement in regard to the construction of the machine, its method of functioning and its thermal efficiency. In this version of the invention it is the internal solid torus which rotates, the part of the machine containing the hollow torus remaining stationary. Thus the part which remains stationary contains the hollow torus containing the helicoidal-spiral grooves in which the vanes of the valve device engage, forming successive compression and expansion chambers. The body of revolution forming the rotor of the machine consists of a rotating shaft and, fixed to the shaft, two bodies of revolution in the form of toruses which are coaxial with the shaft. The stator embraces the two toruses of the rotor and consists of a central part, situated between the two rotor toruses. The central part has surfaces in the form of hollow toruses, each containing a helicoidal-spiral groove whose walls closely embrace, with their edges, the toruses of the rotor. Each rotor torus has a projection, in the region of smaller rotor diameter, in the form of a body of revolution. The projection has the shape of a truncated cone which has a hollow interior. The axis of the truncated cone is coaxial with the axis of the machine. The projection has a surface which is adjacent to a part of complementary shape of the internal surface of the stator, situated between the rotor shaft and the hollow toruses. There is very little clearance between the projecting part of the rotor torus and the complementary surface of the stator.

This arrangement provides considerable advantages. In the first place the machine is more rigid, due to the fact that the parts forming the hollow toruses containing the helicoidal-spiral groove, these parts having relatively thin walls, are now stationary parts and are therefore not subjected to centrifugal forces. If these thin walled parts are subjected to centrifugal forces they tend to deform, reducing the working clearances and giving rise to friction. Furthermore in the present version of the machine the rotating parts are more compact and are situated closer to the axis of rotation of the machine. This alone reduces deformations and stresses.

In the present version of the invention better cooling is provided for the rotor and the stator. These parts are cooled internally. The rotor contains a cooling chamber which cools its entire working surface. Similarly the stator has a cooling chamber which cools the working surface of the hollow torus. The machine is equipped with four valve devices with peripheral vanes. Each valve device is driven in rotation by a drive system which applies drive directly to the vanes. The driving device is in the form of a stationary helicoidal-spiral rib of little height and of truncated conical cross section. The rib projects from the outer surface of a cylindrical sleeve which surrounds the rotor axle in the region between the rotor toruses. The sleeve is fixed to the stator. The helicoidal-spiral driving rib drives the vanes of each valve device directly, this arrangement considerably reducing friction between the vane edges and the walls of the helicoidal-spiral groove in the hollow torus of the stator. The seal between each compression or expansion chamber and the surface of the rotor torus is improved in that the working edge of each helicoidal-spiral rib of the hollow torus has a working edge of flattened shape. This is the edge which is adjacent to the surface of the rotor torus. The flattened edge extends perpendicular to the rib and it working face, adjacent to the surface of the rotor torus, contains a large number of fine grooves which provide a good seal between neighbouring compression or expansion chambers.

In this version of the invention the machine has a rotor **101**, a stator **102** and a double precompressor **103**. The rotor **101** consists of a rotating shaft **104** situated on the axis of the machine, two bodies of revolution **105** and **106**, both having the same shape and mounted facing each other, symmetrically on each side of the middle part of the stator **102**. Each body of revolution **105, 106** consists essentially of a torus split axially into two parts. The torus is fixed to the machine shaft **104** by means of a part **107,108** which is a body of revolution. The cross section of the part **107,108** is approximately a truncated cone. Near its peripheral edge each rotor has a part **109, 110**, in the form of a body of revolution. The outer surface of the part **109,110** is adjacent to peripheral edges **111,112** of the outer parts **113, 114** of the stator **102**. Between the parts **109, 110** of the rotor and the peripheral edges **111, 112** of the stator there is a pressure seal, for example a labyrinth seal. The outer walls **113,114** of the stator **102** are in the form of hollow toruses. Parallel to each of these wals there is a second wall **115, 116**, the arrangement forming a chamber **117, 118** through which cooling fluid flows for cooling the stator. Each chamber **117, 118** contains deflector vanes **119** forming a multiple rib inside the chamber. Each wall **115, 116** is in the form of a hollow torus. The inner surface of the hollow torus, that is to say the surface facing the rotor torus, has projecting helicoidal-spiral ribs **120, 121**. The working edge **122, 123** of each rib is adjacent to the surface of the rotor torus **105, 106**, leaving only a very small clearance between the surfaces. The helicoidal-spiral rib **120, 121** is continued inwards until it comes quite close to the machine shaft **104** in the region of a projection **124, 125** of the rotor torus **105, 106**, the projection being in the form, in cross section, of a truncated cone, which is hollow inside. In the interior of each rotor torus **105, 106** there is an internal chamber **126** containing radial vanes. The chamber **126** is adjacent to the internal surface of the torus and contains a circulating cooling fluid. The cooling chamber **126** extends around at least half of the periphery of the rotor torus **105, 106**. Each cooling chamber **126** is connected through a channel **127** to a source of cooling fluid which can for example be air. The cooling air leaves the cooling chambers **126** through outlet ports in the walls **109, 110** of the rotor toruses **105, 106**, the air escaping to the external atmosphere through a volute which is not shown in the drawing. The source of cooling fluid is preferably, in this version of the invention, a double precompressor **103** in the form of a impeller. The precompressor **103** consists of, on the one hand, a two-part centrifuge **128** and, on the other hand, a second centrifuge **129** downstream of the first. The second centrifuge **129** is situated upstream of an inlet volute which will be described in greater detail further below with the help of FIG. **24**. The air is delivered through this volute to the first compression chamber formed by the helicoidal-spiral rib **120, 121**, by the



rotor torus **105, 106** and by the vanes **130** of the valve device **131**. Each valve device **131** has four vanes which rotate in an axial plane of the machine. A valve device **131** is shown in greater detail in FIG. **27**. Each rotor torus **105, 106** has two oppositely situated valve devices **131**, which are mounted to rotate on shafts between the two half-toruses which together make up each rotor torus.

The air leaves the first centrifuge on the one hand through a volute **132** for the cooling air and, on the other hand, through a diffuser **133** and a volute **134** for the precompressed air which is fed to the centrifuge **129**, from which the air leaves through a double volute **135**, which is shown in greater detail in FIG. **24**. The double volute **135** progressively slows down the current of compressed air leaving the centrifuge **129**, so that this air reaches the inlet of the first compression chamber in the helicoidal-spiral groove almost without any change of velocity. In a variant of the invention, in which the fluid leaving the first centrifuge for the purpose of cooling the chambers **117, 118** in the stator is not air but water, the collector volute **132** is replaced by a radiator **132'**, represented by a broken line in the drawing.

The stator **102** has a central sleeve **136** whose two ends, near where the rotor toruses are fixed to the shaft, have helicoidal-spiral external truncated ribs **137** of little height. These ribs act as guides guiding the edges of the vanes of the valve device. The helicoidal-spiral rib **137** is a truncated part of the helicoidal-spiral rib **120**, as shown in greater detail in FIG. **25**. The sleeve **136** also has two bodies of revolution **138, 139** which have shapes complementary to the two parts **124, 125** of the rotor toruses **105, 106**, so that there remain very little clearance between these surfaces. The sleeve **136** has a further truncated helicoidal-spiral rib **140** of little height, along which are guided the middle notches in the edges of the valve device vanes (compare FIG. **25**).

Projecting from the bottom of each helicoidal-spiral groove between the ribs **120, 121** there is a middle helicoidal-spiral rib of little height **120'** which forms a continuation of the rib **140**.

The middle part of the stator **102**, near the parts **124, 138** and **125, 139**, contains two openings **141, 142** which are connected by channels **143, 144**, shown in broken lines, to an outlet channel **145** for the compressed air. The channels **146** and **147** feed cooling air to the cooling chambers **117** and **118**. The channels **148** and **149** feed precompressed air from the double volute **135** to the compression chambers of the two parts of the machine (a broken line leaving the outlet **149** indicates the channel which is connected to the inlet of the machine, at the right near the bottom in the drawing). Finally the end of the machine opposite the precompressor is closed by a part **150** of the stator, this part being mounted by means of a bearing on the axle of the machine.

FIG. **24** represents diagrammatically the double volute **135** situated at the outlet of the second precompressor centrifuge **129**, the figure being a transverse section of the machine at the outlet of the centrifuge **129**.

In FIG. **25** a vane **130**, fixed to the hub of a valve device (not shown) by two screws **151**, is guided by a notch **152** in its peripheral edge, the notch engaging over the helicoidal-spiral truncated rib **140** of the sleeve **136** fixed to the stator **102**. The notch **152** engages precisely with the surface of the rib **140**, so that the vane **130** is precisely guided along the rib **140**. The figure also shows the other truncated rib **137** of little height, which precisely continues the helicoidal-spiral rib **120**. In view of the fact that there is extremely little clearance between the parts **140** and **152**, these parts acting as guides for the vane, no friction occurs between the parts **130** and **120**, **137** between which there is more clearance.

FIG. **26** shows two vanes **130** attached by screws **151** to the hub (not shown) of a valve device, the vanes engaging in a helicoidal-spiral groove, for example **120** or **121**. The rib **120** has a flattened end **152** extending perpendicular to the axis of the vane, the face **153** of the end being adjacent to the outer surface of the torus (represented diagrammatically by the line **154**). The face **153** has a large number of fine grooves **155** whose function it is to improve the seal between the compression and/or expansion chambers.

FIG. **27** is a diagrammatical section through the machine, taken in a plane containing the axis of a valve device **131** which consists of a hub **156** and vanes **130**. The hub rotates on a pin **157** which passes through a central bore in the hub. The vanes **130** are attached by screws **151** to the periphery of the hub. The two half-toruses **158, 159** completely enclose between them the hub. The two half-toruses **158, 159** are joined together for example by bolts **160**. The hub **156** rotates between inclined ball or roller bearings **161**.

The machine can be in the form of an assembly of parts which can if desired be of different materials of construction, in particular materials having different degrees of heat resistance, different mechanical strengths and different coefficients of friction. In the process of assembling the valve devices, the two half-toruses can first be screwed together with the hub of the valve device between them, the vanes being screwed to the hub subsequently.

The machine functions as follows:

The precompressor **103** constantly feeds air to the cooling circuits **146, 147, 117, 118** and also air to the second precompressor **129**, through a diffuser **133**. The precompressed air passes through the volutes **148** and **149** into the two helicoidal-spiral grooves limited by the ribs **120, 121**, the toruses **105, 106** and the vanes **130** of the valve devices **131**. With rotation of the toruses of the rotor, the air in the chambers is progressively compressed between the vanes. The compressed air leaves the chambers through the openings **141** and **142**, passing through the channels **143, 144** into a common air outlet channel **145**. The cooling air leaves the cooling chambers **117, 118** through channels **143'**, **144'**, **145'** arranged in much the same way as the channels **143, 144, 145.** Moreover cooling air entering channels such as the channel **127** in the toruses **105, 106** escapes through openings such as **109'** in the parts **109** and **110** of the toruses, the air finally leaving through a volute, not shown in the drawing, which communicates with the external atmosphere.

FIGS. **28** to **33** show very diagrammatically various different ways of assembling the machine according to the invention.

In FIGS. **28** and **29**, the two parts of the machine are indicated in a general way at a and b. In FIG. **28**, which is the reverse of FIG. **23**, the two parts can take the form of two compressors functioning either in parallel or in series, the air circulating as indicated by the arrows.

FIGS. **30** and **31** show two ways of assembling the machine according to the invention. The connecting channels between the two symmetrical parts a and b of the machine allow the output of the machine to be increased. FIGS. **32** and **33**, on the other hand, show two arrangements in which the connecting channels between the two parts a and b of the machine allow the pressure to be increased in the air passing through the machine.

In these figures it should be observed that if the machine is a motor, the parts a are the compressor, the parts *b* representing the part of the machine containing the expansion chambers. This part of the machine can be developed to provide a more complete working stroke during the expansion of the gas.

What I claim is:

**1.** Rotary machine which can be used as one of a motor, a compressor, a motor-compressor and the like, comprising a first and a second body of revolution, one of which is stationary, the other rotating, the first body of revolution being hollow with an axial central part defining the axis of the machine and the second body being solid and completely surrounded by the said first body, and at least one helicoidal-spiral groove in the surface of the first body, and at least one valve device with peripheral vanes, the valve device rotating in a longitudinal plane of symmetry of the first body, the vanes engaging in the groove in the first body, the wall of the second body co-operating with the vanes to limit successive chambers of variable volume which change the pressure in a fluid, the second body having at least one projecting part, also in form of a body of revolution, the said first body, the surface of which is provided with the said helicoidal-spiral groove, having at least one wall part, obtained by a complete truncature of the ribs of the helicoidal-spiral groove in the region facing said projection and having a shape complementary thereto, there being very little clearance between these parts, the machine comprising also channel means provided in the said first body and having a reduced cross-section and being located in the machine so as to conduct the fluid from the end of the helicoidal-spiral groove, situated above the said projecting part in the direction of flow of the circulating fluid, to the part of the helicoidal-spiral groove, situated below the said projecting part, the said projection of the second body and the said completely truncated part of the first body, facing the projection, which define very little clearance therebetween, preventing a passage of the fluid therethrough and directing the same into the said channel means in such a manner that the fluid is subjected to an additional greater compression.

**2.** Rotary machine according to claim **1**, in which the first body of revolution is a stator, the second being the rotor, the machine having a rotating longitudinal shaft and, fixed to the shaft, two bodies of revolution in the form of coaxial toruses, these parts forming the rotor, and a central part, between these toruses, having working surfaces in the form of hollow toruses containing at least two helicoidal-spiral grooves and ribs which are integral with the hollow toruses and closely embrace at least most of the surface of the rotor toruses, each rotor torus having, near its region of least diameter, a projecting body of revolution, hollow inside, the stator having in this region a wall part of a shape complementary to the projection so that there remains only a very small clearance between these parts.

**3.** Machine according to claim **2,** with a source of cooling fluid, and at least one internal chamber through which the cooling fluid flows, and at least one internal channel, the chamber being inside the rotor torus, near its external surface, the channel in the rotor connecting the source of cooling fluid to the chamber.

**4.** Rotary machine according to claim **3,** with a centrifugal compressor and a volute leading to the ambient atmosphere, the compressor which is fixed to the rotor, being the source of cooling fluid and precompressing the air, a part of the air from the turbine entering the channels near the middle of the rotor, another part flowing out through the volute fixed to the stator.

**5.** Rotary machine according to claim **2,** with a further cooling system entirely enclosing the chambers of variable volume included between the vanes of the valve device, the non-truncated helicoidal-spiral ribs, the bottom of the groove and the working surface of the rotor, this cooling system being in the stator and consisting of an assembly of vanes spaced close together to form a multiple helicoidal-spiral rib in the chamber limited by the middle part of the stator and the wall of the helicoidal-spiral groove, the multiple rib producing in this chamber a multiple channel through which a cooling fluid flows.

**6.** Rotary machine according to claim **2,** with four valve devices disposed symmetrically with respect to the stator and the rotor, each valve device having peripheral vanes which engage in the helicoidal-spiral grooves in the working faces of the hollow toruses of the stator, and a sleeve fixed to the stator and situated near the axis of the machine, and at least one first truncated helicoidal-spiral rib on the sleeve, and a second truncated helicoidal-spiral rib situated in the bottom of the groove of this rib, the truncated helicoidal-spiral ribs serving for guiding and driving the valve devices, whose peripheral vanes engage in the groove of the first rib of little height.

**7.** Rotary machine according to claim **6,** in which each valve device consists of a hub which has a peripheral groove in which are inserted the peripheral vanes, each vane being secured by at least two transverse screws, the hubs rotating in the toruses on inclined roller bearings disposed symmetrically on either side of the plane which contains the valve devices.

**8.** Rotary machine according to claim **6,** with a driving system for driving the valve devices, the driving system consisting of the sleeve fixed to the stator and situated between the parts of the toruses nearest to the rotor shaft, the sleeve having internal surfaces, near its ends, which bear on the shaft, and external end surfaces fixed to the stator, these surfaces having, on the one hand, two truncated helicoidal-spiral ribs of little height for guiding and driving the vanes of the valve devices and, on the other hand, a part which is a body of revolution and forms a part of the wall of the stator, this part having a shape which corresponds to the projection of each rotor torus, in the form of a body of revolution, the second truncated helicoidal-spiral rib having a shape which is the same as that of the truncated helicoidal-spiral rib of little height projecting from the middle of the bottom of each groove between the non-truncated helicoidal-spiral ribs which limit, together with the valve device vanes, the chambers of variable volume.

**9.** Rotary machine according to claim **7,** in which the peripheral edge of each vane has a central notch whose shape is precisely complementary to the shape of the second truncated helicoidal-spiral rib of little height which guides the vane.

**10.** Rotary machine according to claim **9,** in which each of the non-truncated helicoidal-spiral ribs which limit, together with the vanes, the compression and expansion chambers, has a flattened end extending perpendicular to the body of the rib, the working face of the flattened end having a large number of fine grooves for the purpose of producing a better seal between the chambers of variable volume contained between the vanes of the valve devices, the fine grooves being in the faces of the rib ends adjacent to the surface of the rotor torus.

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