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Horst

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[54] **ROTARY ENGINE WITH ROTATABLE THRUST HEADS IN A TOROIDAL CHAMBER**

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[52] **U.S. Cl.**..... **418/172,** 418/188, 418/226, 137/625.17

[51] **Int. Cl.**..... **F01c 1/00,** F03c 3/00, F04c 17/00

[58] **Field of Search** 418/172, 183, 188, 192, 418/226, 227, 233; 137/625.17

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Primary Examiner—John J. Vrablik

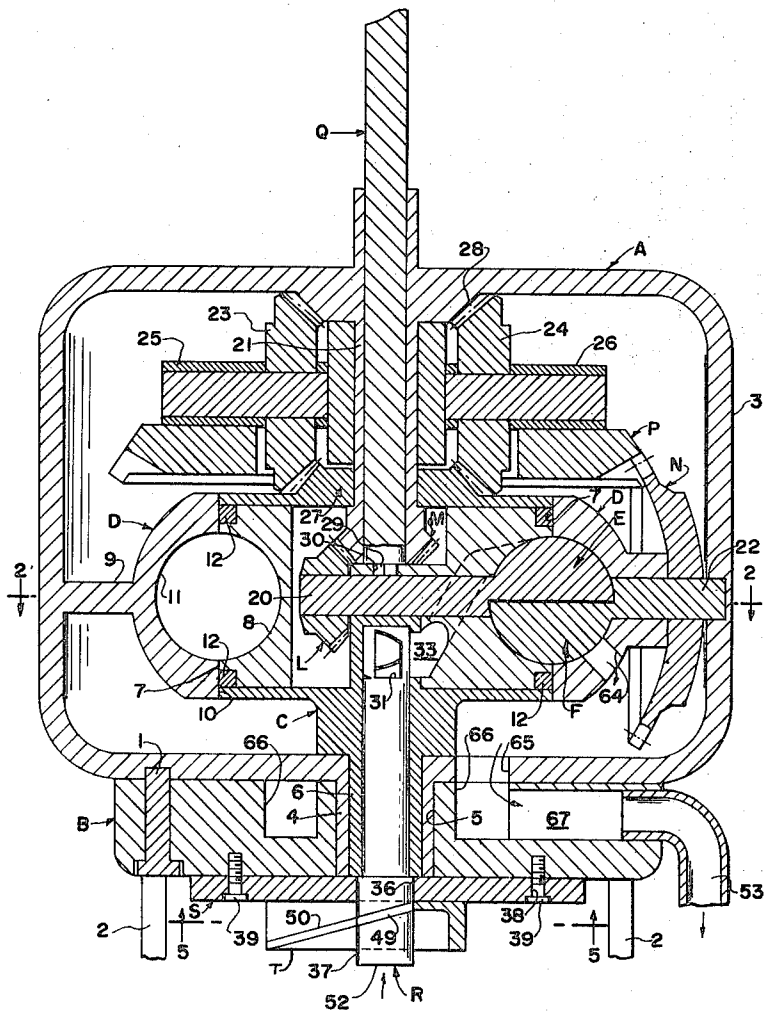
Attorney, Agent, or Firm—Limbach, Limbach & Sutton

[57] **ABSTRACT**

An outer member and an inner, rotatable member together form the greater part of a toroidal chamber assembly therebetween, each member rotatably carrying a hemispherical thrust head which is slidably received in the opposite semi-torodial chamber of the other member and constituting a sliding closure therein. Each thrust head is rotatable on an axis that extends radially from the common axis of rotation of both members and a planetary gear mechanism interconnects the two thrust heads so as to rotate them at a speed such that they are able to pass each other during the rotation of the inner member with respect to the outer member. The inner rotatable member is directly connected to a driven output shaft so that the shaft will rotate at the same speed as the inner rotatable member.

A modified form of my invention makes use of a similar mechanism as is in the preferred form but the outer member is freed so as to rotate in the opposite direction to that of the inner rotatable member. Furthermore, the outer rotatable member is directly connected to a hollow second driven output shaft that is concentric with and rotates in the opposite direction to the output shaft that is directly connected to the inner rotatable member.

14 Claims, 16 Drawing Figures



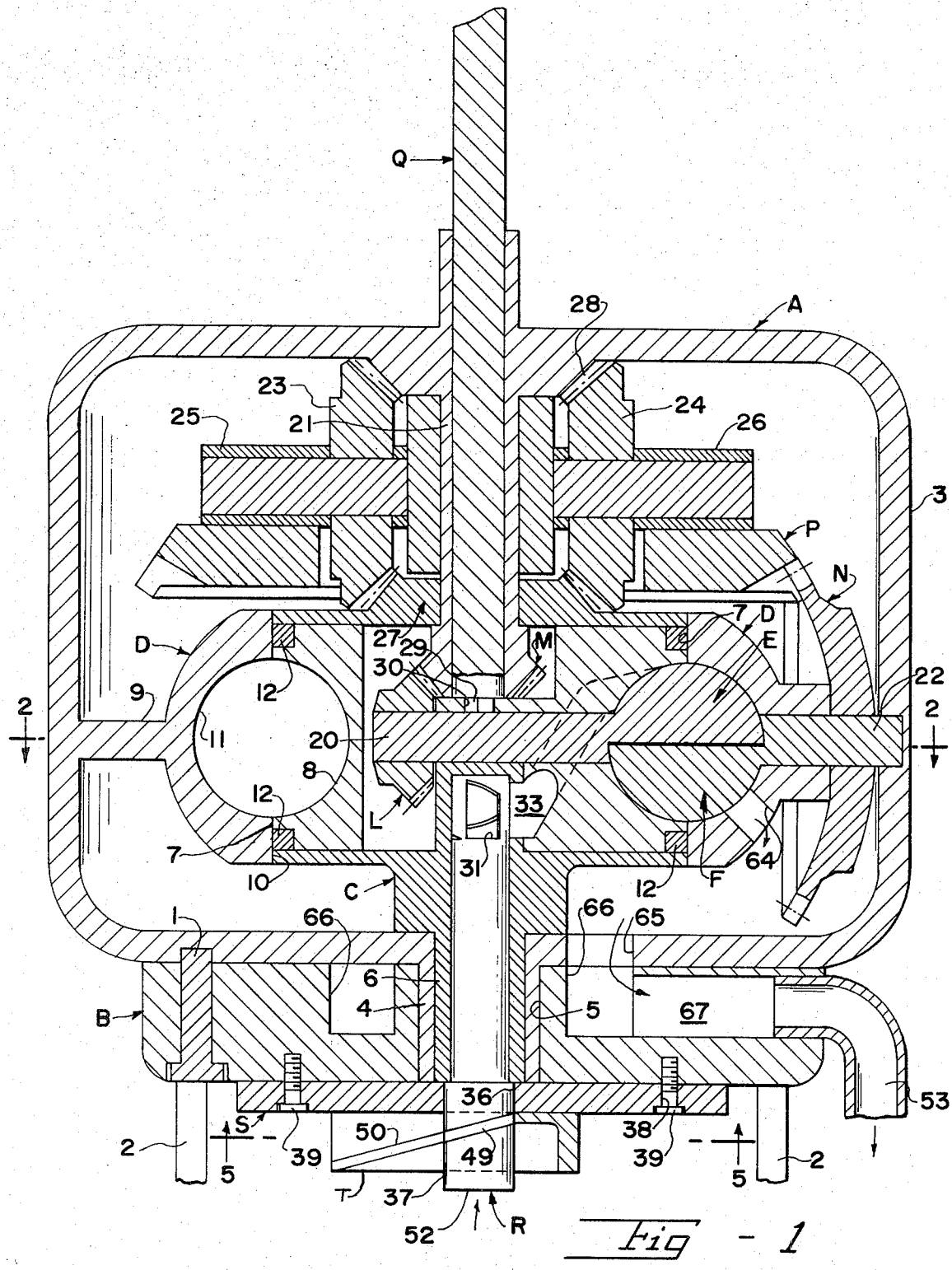
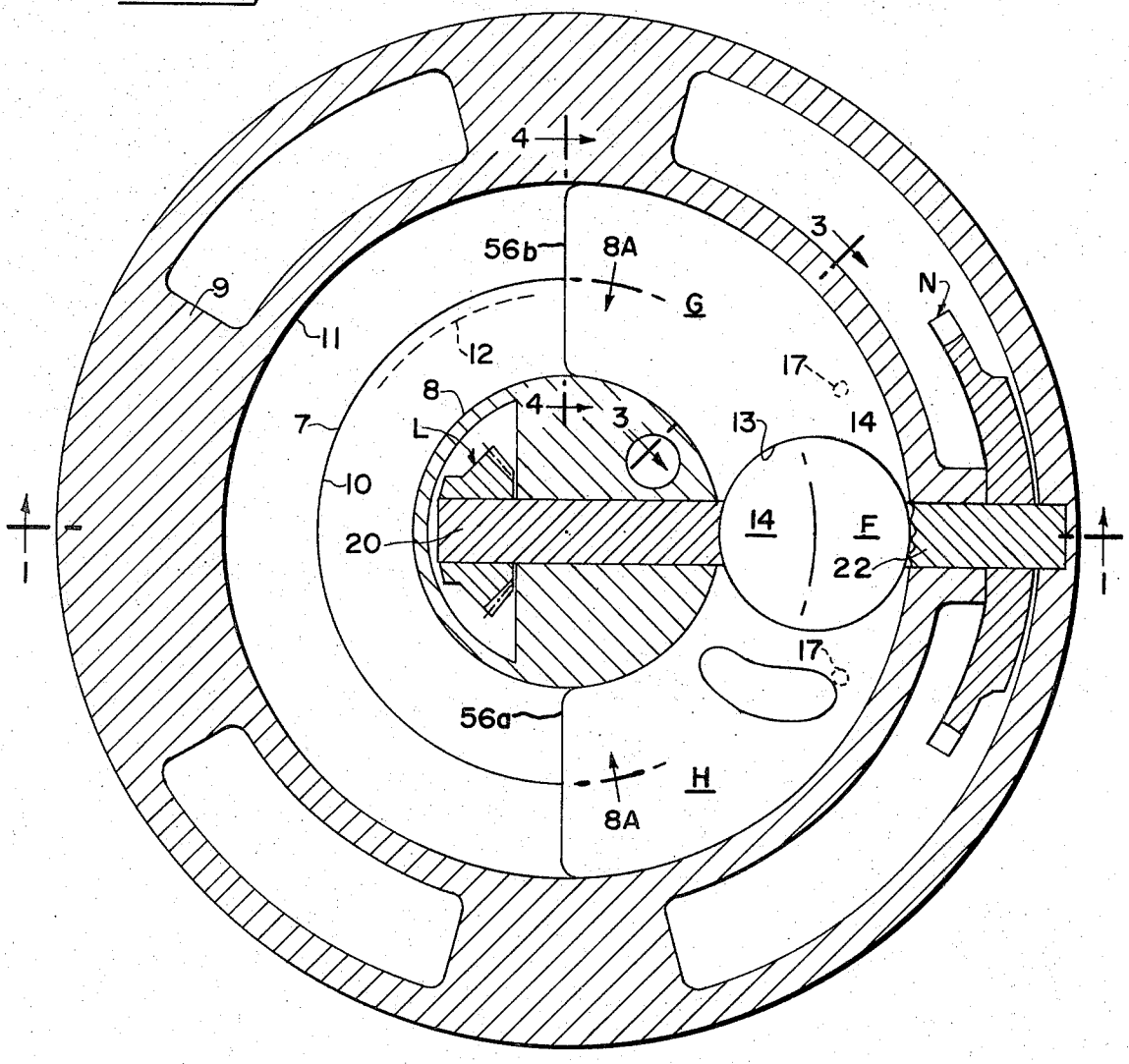

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Fig - 1

Fig-2



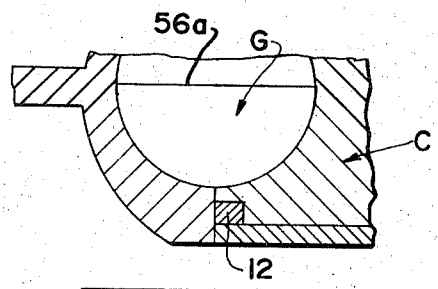


Fig 4

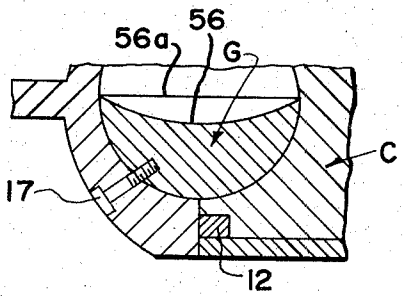


Fig 3

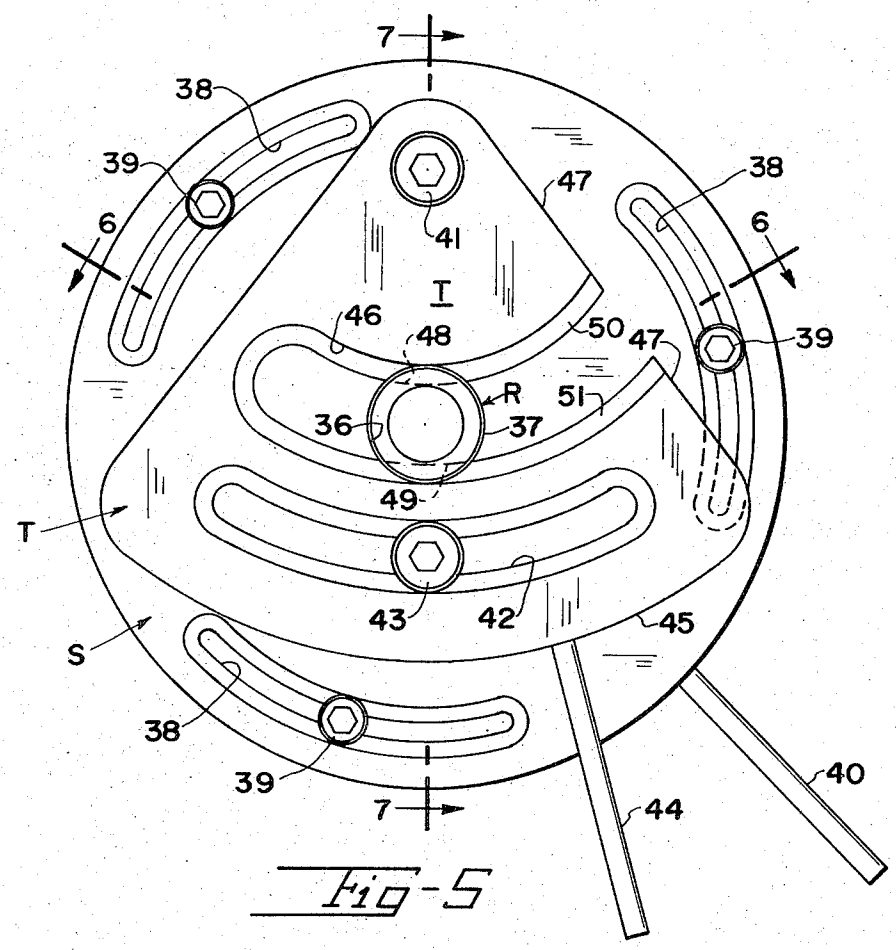


Fig-5

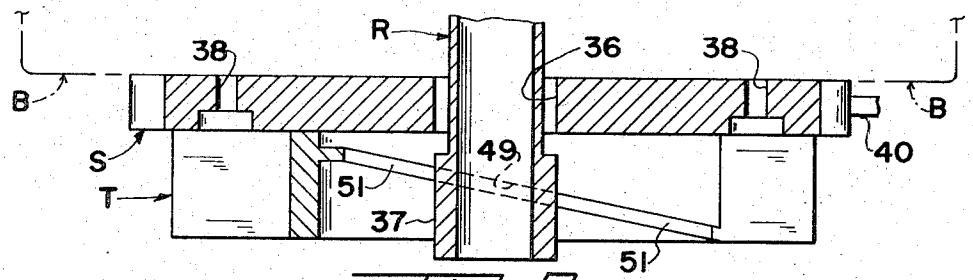


Fig-6

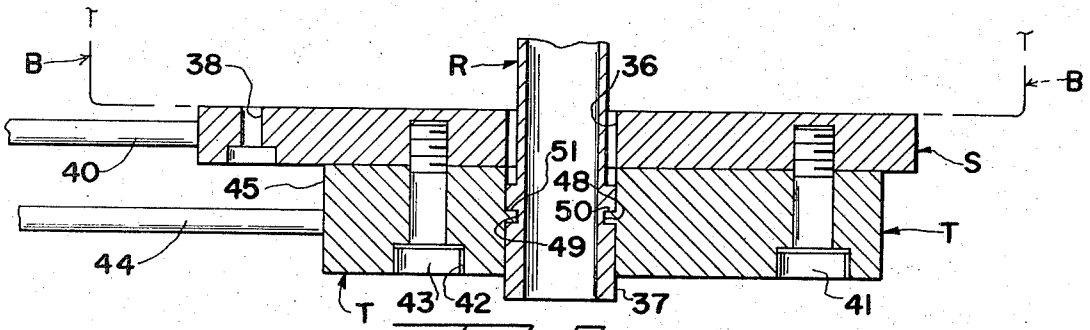


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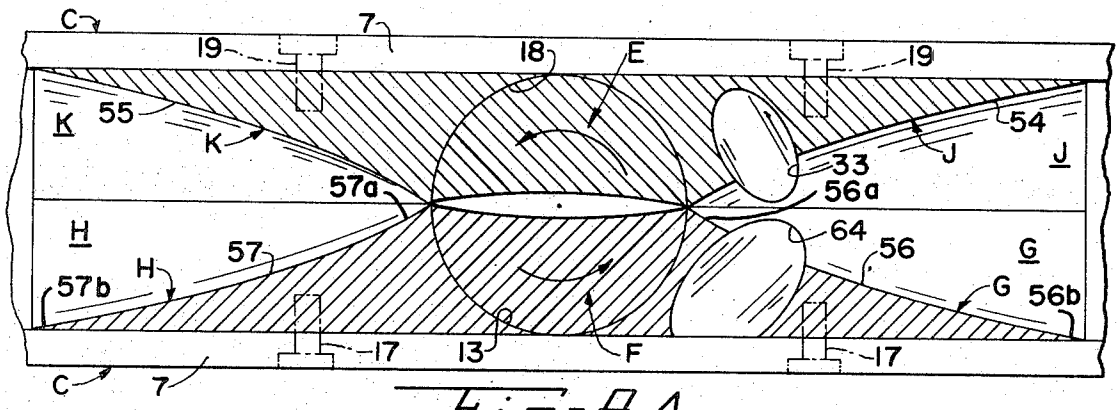


Fig-8A

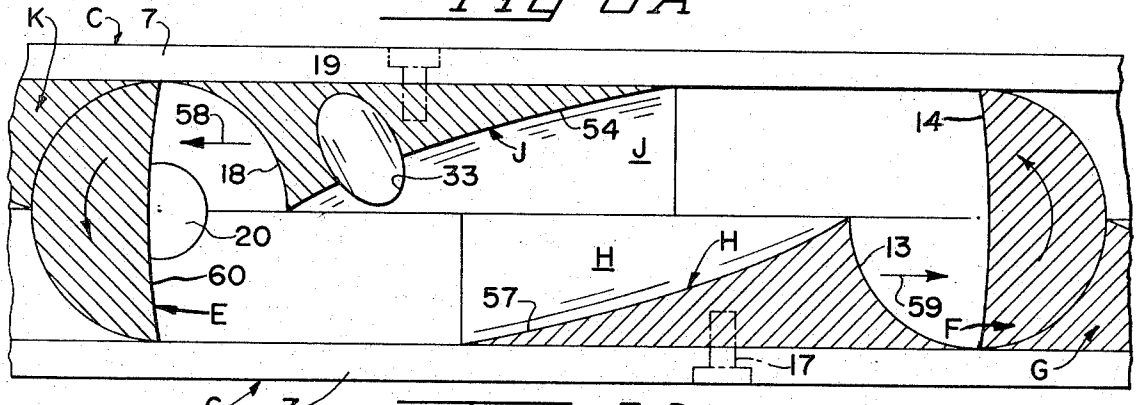


Fig-8B

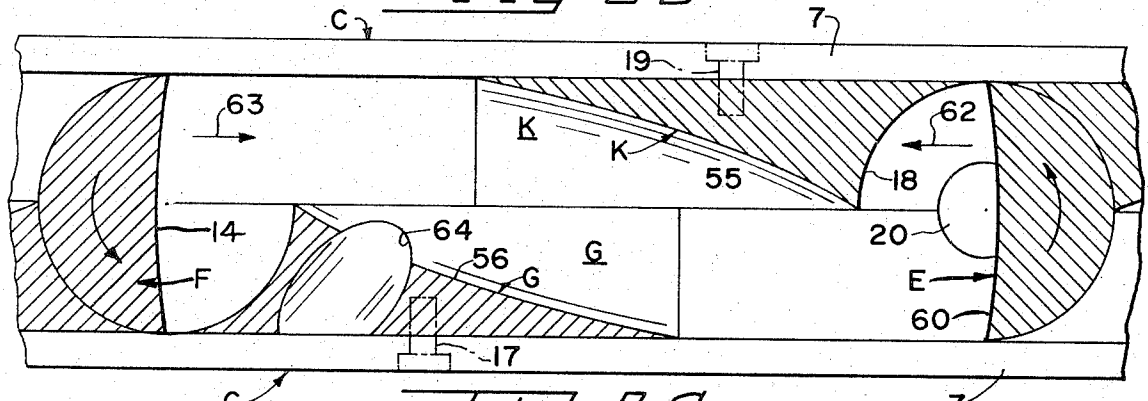


Fig-8C

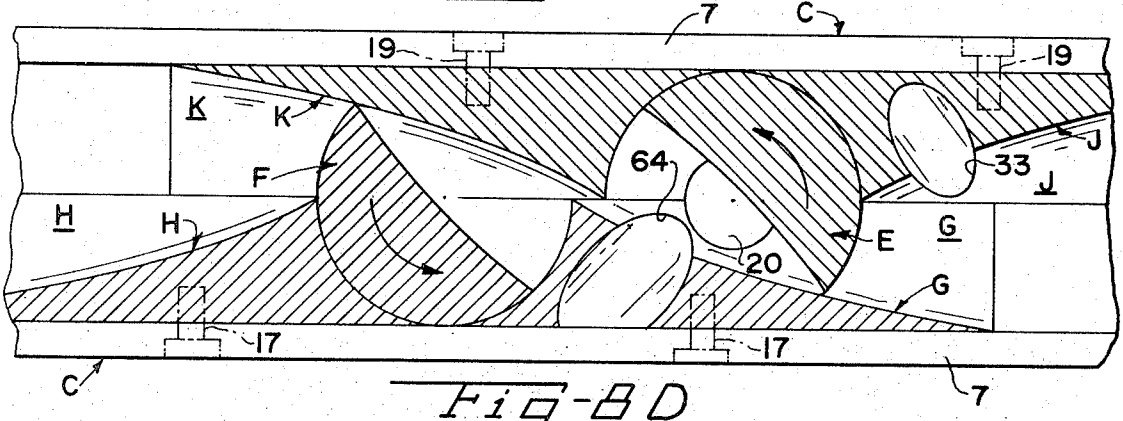


Fig-8D

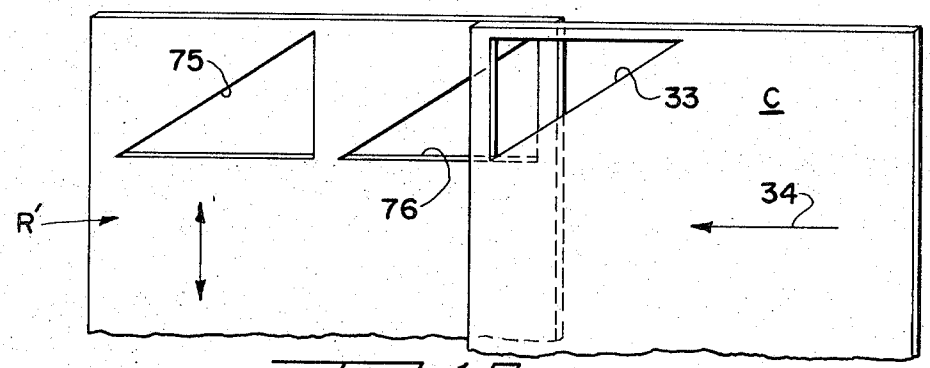


Fig-12

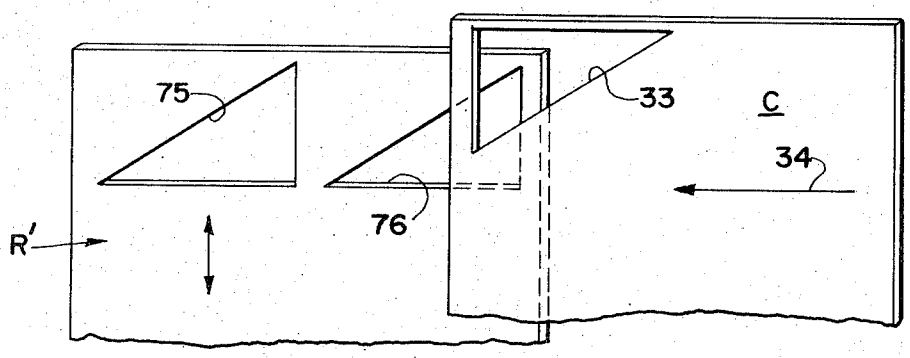


Fig-13

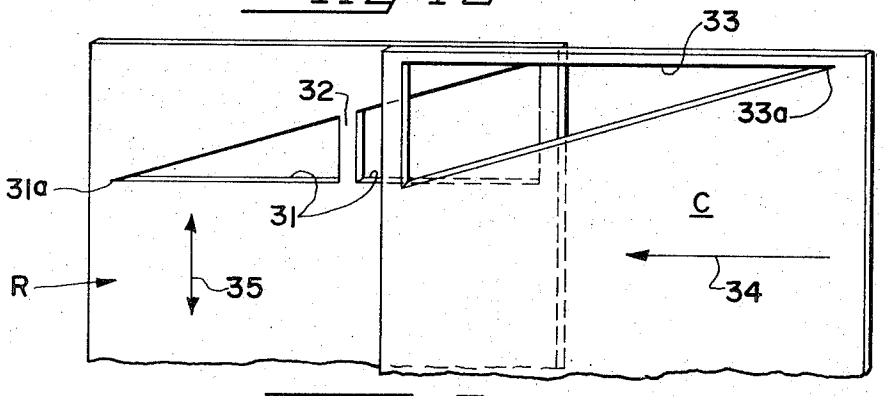


Fig-9

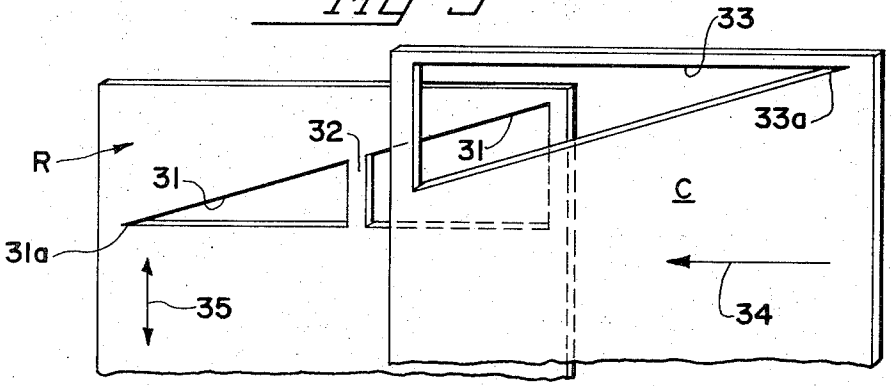


Fig-10

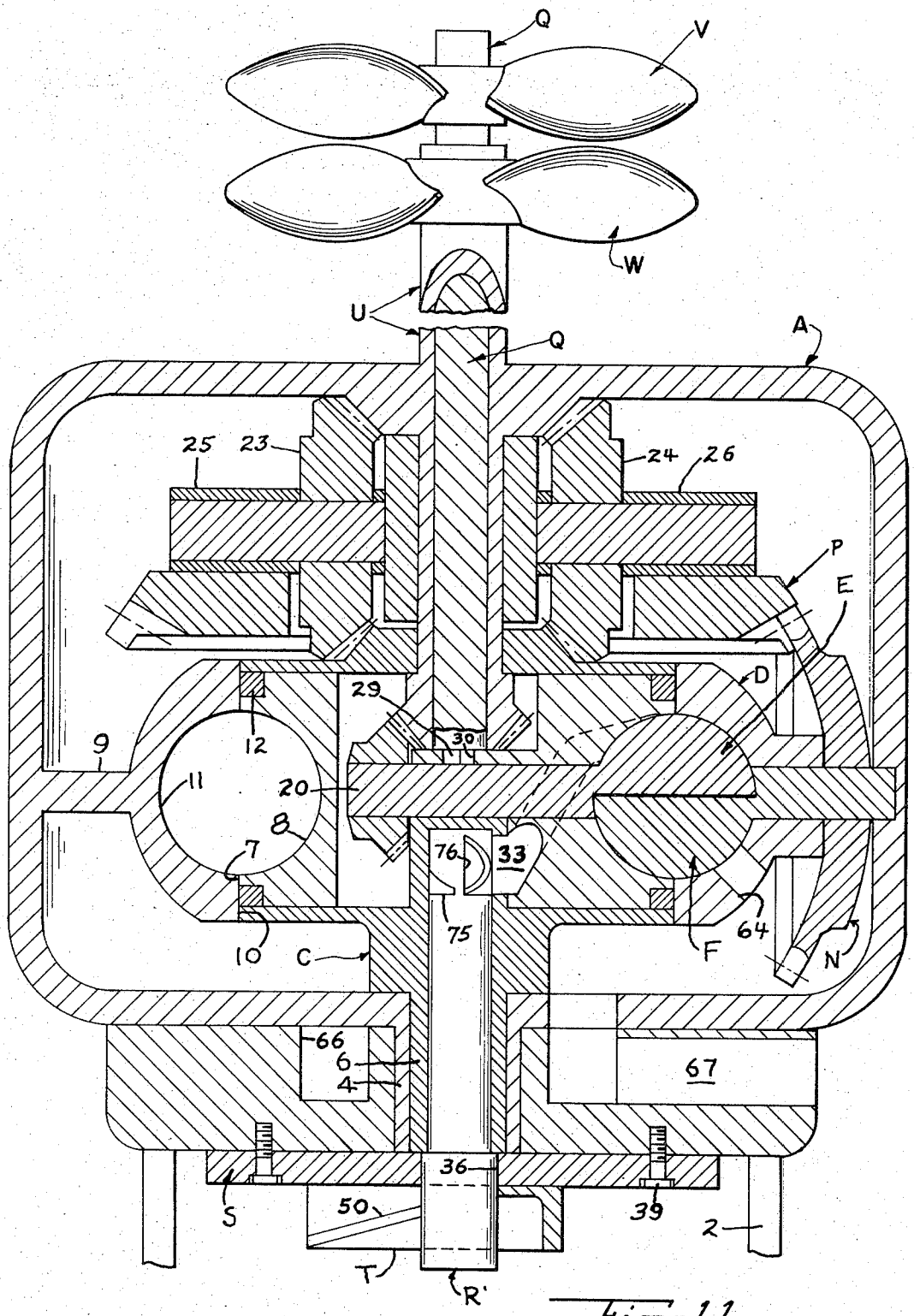

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Fig-11

ROTARY ENGINE WITH ROTATABLE THRUST HEADS IN A TOROIDAL CHAMBER

BACKGROUND OF THE INVENTION

The invention relates to a positive displacement rotary engine and more particularly to a dual rotor engine for use with an expandable fluid such as a compressed gas or steam.

A dual rotor engine of the general type described in this application is disclosed in my U.S. Pat. No. 3,521,979, issued July 28, 1970. The engine disclosed in that patent has two oppositely rotating rotors which form the greater part of a radially disposed toroidal chamber assembly therebetween such that the toroidal assembly is parted into two lateral halves or rotors. Each rotor carries a thrust head that is slidably received in the opposite semi-toroidal chamber and the thrust head rotates on its own axis that extends radially from the common axis of the rotors. The dual-drive rotary engine shown in the patent has a single output shaft.

Such engines have many advantages over conventional reciprocating engines and turbine engines such as a high power to weight ratio, near constant torque through a complete cycle of rotation, a reduction in the number of working parts and vibration, counterbalanced working parts, and a relatively small size in relation to output power.

The engine described in U.S. Pat. No. 3,521,979 nevertheless has certain disadvantageous features. No means for controlling the power speed or efficiency of the engine is disclosed in the patent. Another disadvantage of the engine shown in the patent is that the outermost sealing ring between the two rotors is subjected to the greatest peripheral speed of the two rotors sliding in opposite directions with respect to each other. This causes undesirable excessive wearing of the sealing ring.

SUMMARY OF THE INVENTION

The above and other disadvantages are overcome by the present invention of a dual rotor, rotary engine comprising a pair of inner and outer members rotatable with respect to each other about a common axis, the inner member having a circular outer periphery and the outer member having a circular inner periphery which slidably contacts the outer periphery of the inner member, the inner member having a semi-toroidal groove formed in its outer periphery and the outer member having a complimentary semi-toroidal groove formed in its inner periphery and facing the semi-toroidal groove in the inner member to form a complete toroidal chamber therewith. The inner member carries a first thrust head receivable in the toroidal chamber, the thrust head being mounted on a shaft which is rotatable in the inner member. The outer member carries a second thrust head receivable in the toroidal chamber, the second thrust head being mounted on a shaft which is rotatable in the outer member.

The first thrust head is shaped so as to conform to the half cross-sectional shape of the semi-toroidal groove. The first thrust head is rotatably receivable in a first pocket formed by a first pair of arcuate inserts, one being disposed on each side of the first thrust head and each being secured to the inner member. The inserts have contoured, inclined surfaces extending from the pocket and terminating in feathered edges that merge into the surface of the toroidal chamber. The second thrust head corresponds in shape to the first thrust head and is rotatably receivable in a second pocket formed by a second pair of arcuate inserts, one being disposed on each side of the second thrust head and each being secured to the outer member. The second pair of inserts have contoured surfaces extending from the second pocket and terminating in feathered edges that merge into the surface of the toroidal chamber. Gear means are provided for operatively connecting the inner and outer members together so that they can rotate in opposite directions relative to each other. These gear means also rotate the thrust heads so as to continuously close the cross-sectional area of the toroidal chamber and the restricted cross-sectional area caused by the inserts, the thrust heads being rotated on their own axes so that they will pass each other during each revolution of the rotors in opposite directions. In the preferred embodiments described herein, the thrust head shafts extend radially with respect to the common axis of rotation of the inner and outer members. Means are provided for delivering an expansion fluid into the chamber portion lying between the two thrust heads for moving them apart and for exhausting the fluid from the chamber portion in which the two thrust heads are moving toward each other.

In a first embodiment, the inner member is rotatable with respect to the outer member, which is held stationary. A first output shaft is operatively connected to the inner rotor in the first embodiment. In a second embodiment the inner and outer members both rotate and in opposite directions. A second output shaft, coaxial with the first output shaft, is connected to the outer rotor. In the second embodiment the means for operatively connecting the inner and outer members together include gearing that will cause the two members to rotate in opposite directions and in synchronization with each other.

In both preferred embodiments each thrust head has one, near planar, slightly concave surface and the means for rotating the inner and/or outer members and the thrust heads cause the thrust heads to be entirely received within their pockets at the moment the two thrust heads pass each other, in the toroidal chamber. The near planar surfaces of both thrust heads lie parallel to each other at the moment of passing. The cross-sectional shape of the toroidal groove is circular and the two thrust heads are hemispherical in shape.

For purposes of this description, the inner and outer members will hereinafter be referred to as "rotors," though it is to be understood that in some embodiments either of the rotors may be held stationary with respect to the other rotor.

The means for delivering an expansion fluid such as steam or compressed gas, for example, into the toroidal chamber include a valve for controlling the quantity and the early or late cut-off of steam or compressed gas entering the chambers for controlling the operating efficiency by the rotary engine and the energy of the output shaft. The sleeve valve is hollow and is axially aligned with the common axis of the two rotors. The valve receives the steam or gas under pressure and has an outlet port registering with an inlet port in the inner rotor that communicates with the toroidal chamber. The sleeve valve is movable in the direction of its length and is rotatable about its longitudinal axis so that the location of the sleeve outlet port with respect to the inlet port can be adjusted to control both the duration

of the injection of steam or gas into the engine and its timing, respectively, to thereby control the energy and efficiency and the speed of the output shaft.

The means for moving the sleeve valve include a timer disc rotatable about the common axis of the two rotors and having a central opening through which a portion of the sleeve valve extends. The timer disc has a handle for swinging the disc and sleeve valve through a desired arc. The sleeve valve-moving means also includes a sector-shaped member pivoted off center with respect to the timer disc and having an arcuate slot for receiving a portion of the sleeve valve, the center of curvature of the arcuate slot coinciding with the axis of the pivot interconnecting the sector-shaped member with the timer disc. The arcuate slot in the sector-shaped member has inclined and inwardly extending ribs that are slidably received in diametrically opposed grooves provided in the outer cylindrical surface of the sleeve valve portion received in the arcuate slot. The sector-shaped member also has a handle for swinging the sector-shaped member about its pivotal connection with the timer disc for moving the sleeve valve in the desired direction along its length. Swinging the timer disc handle twists the sleeve valve about its longitudinal axis.

In the second form of the invention described herein, the outer rotating member is connected directly to a hollow output shaft that encloses a portion of the output shaft which is directly connected to the inner rotating member. The outer and inner rotors in this second form of the invention rotate in opposite directions with respect to a support base and this will cause both of the output shafts to rotate in opposite directions. The inner output shaft extends beyond the hollow output shaft.

The present rotary engine differs from the rotary engine shown in U.S. Pat. No. 3,521,979 in that the present engine has an outer member with a semi-toroidal groove therein and an inner, concentric rotatable member with a complementary, semi-toroidal groove therein, rather than a nearly toroidal assembly that is formed from two, parallel, lateral rotor halves. Thus in the patented engine shown, the plane that lies between the two rotors is normal to the common axis about which the two rotors rotate; whereas, in the present invention the inner and outer rotatable members are concentric and rotate about a common axis. A common, theoretical, cylindrical surface whose axis of rotation coincides with the common axis for the two rotating members can be passed between the abutting surfaces of these two members. As mentioned above, in the patented engine the outermost sealing ring that lies between the two oppositely rotating rotors is positioned so as to encircle the toroidal chamber formed by the rotors. This sealing ring is therefore at the greatest distance from the axis of rotation of the rotor halves and is subjected to the greatest peripheral speed of the rotors. It must nevertheless withstand a considerable pressure from the steam or other expandable gas that is delivered to the chamber.

With the present rotary engine the two sealing rings positioned between the inner and outer rotors at the juncture of their abutting circular surfaces will have a smaller diameter than the outer sealing ring in the patented rotary engine. The peripheral speed of the two rotatable members of the present invention at their juncture is less than that at the common outer periphery of the two rotor halves in the patent engine and therefore the sealing rings in the present rotary engine will be subject to less wear from the rotating members than the large diameter sealing ring in the patented engine.

It is therefore an object of the invention to provide a rotary engine in which there are no reciprocating parts and the number of working parts is greatly reduced over an internal combustion engine that makes use of reciprocating pistons in cylinders and operates either on the two or four-cycle principle.

It is another object of the invention to provide a rotary engine in which vibration is reduced because there are no reciprocating parts and all revolving parts are properly counterbalanced.

It is still another object of the invention to provide a rotary engine which operates by an expanding fluid such as steam or compressed air.

It is further an object of the invention to provide a rotary engine which requires far less space and is lighter in weight while developing the same or a greater torque than a standard internal combustion engine.

It is further an object of the invention to provide a rotary engine with a novel speed, power and efficiency control.

It is further an object of the invention to provide a rotary engine with a more reliable sealing mechanism between the rotating parts.

It is still a further object of the invention to provide a dual output, direct drive rotary engine.

These and other features and advantages will become more apparent upon a perusal of the following specifications taken in conjunction with the accompanying drawing wherein similar characters of reference refer to similar structures in each of the several views.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a vertical section through a rotary engine of a first embodiment of the invention where only one power take-off shaft is used and it is taken generally along the line **1—1** of FIG. **2**;

FIG. **2** is a horizontal section through the engine and is taken generally along the line **2—2** of FIG. **1**;

FIGS. **3** and **4** are vertical sections, with portions broken away, through different parts of the two semi-toroidal chambers and are taken generally along the lines **3—3** and **4—4** of FIG. **2**, respectively;

FIG. **5** illustrates the speed and efficiency control mechanism for the engine and is taken generally along the line **5—5** of FIG. **1** when looking upward in the direction of the arrows in that FIG.;

FIGS. **6** and **7** are transverse sections through the speed control mechanism and are taken generally along the lines **6—6** and **7—7**, respectively, of FIG. **5**;

FIG. **8A** is an arcuate, vertical section taken between the outer member and the inner rotating member and is taken along the arcuate, dashed line **8A—8A** of FIG. **2**, and shows the two thrust heads in the positions they assume as they pass each other during the operation of the engine;

FIGS. **8B**, **8C** and **8D**, are sections similar to that of FIG. **8A**, except that these latter three sections show the different positions assumed by the rotating thrust heads during one complete revolution of the inner rotary member with respect to the outer member;

FIGS. **9** and **10** illustrate diagrammatically the different positions assumed by the control valve having a single port for controlling the speed of the engine;

FIG. 11 is a vertical section through a modified form of the rotary engine where the outer and inner members rotate in opposite directions and are directly connected to two output shafts rotating about a common axis, one of the output shafts being hollow and enclosing a portion of the other output shaft; and

FIGS. 12 and 13 illustrate diagrammatically the different positions assumed by a control valve having double outlet ports for controlling the speed of the modified engine depicted in FIG. 11.

DESCRIPTION OF CERTAIN PREFERRED EMBODIMENTS

Referring now more particularly to FIGS. 1 and 2, an outer member or stationary housing A is mounted on a base member B and one or more bolts 1 extend upwardly from the base and into the housing A for preventing rotation of the housing A with respect to the base B. Any other means desired may be used for securing the housing A to the base B. The base is supported by legs 2 or any other suitable supporting means. It will be noted that the stationary outer member or housing A has a cylindrical wall 3 and a lower central tubular portion 4 that extends downwardly and into a central bore 5 in the base.

Within the stationary housing A is rotatably mounted an inner rotor indicated generally at C. This inner rotor C has a central tubular portion 6 that is rotatably received within the tubular portion 4 of the stationary housing A. Also the inner rotor C has an outer, peripheral surface 7 that has a semi-toroidal groove 8 therein (see also FIG. 7 where a portion of the semi-toroidal groove is shown).

An outer member D is mounted within the housing A and is connected thereto by a web 9. The outer member D has an inner, peripheral surface 10 and this surface has a semi-toroidal groove 11 therein that is complementary with the semi-toroidal groove 8 in the inner rotor C, the two semi-toroidal grooves forming a toroidal chamber that substantially encircles the inner rotor C. Circular sealing rings 12 are arranged on each side of the semi-toroidal groove 8 and are carried by the inner rotor C and slidably contact the adjacent circular, inner, peripheral surface 10 of the outer member D for forming a liquid tight seal therewith.

A thrust head E is provided for the inner rotatable member C and a thrust head F is provided for the outer member D. The thrust head F will first be described in detail since this is illustrated in both FIGS. 1 and 2. The particular thrust head F is hemispherical in shape and it is rotatably received in a hemispherical pocket 13 formed by inserts G and H (see FIG. 8A) that are placed in the lower quarter of the semi-toroidal groove 11 in the outer stationary member D and extend into the lower quarter of the semi-toroidal groove 8 in the inner rotatable member C. In other embodiments the shape of the thrust heads and pockets can take other shapes, such as hemi-cylindrical, for example, to mach semi-toroidal grooves in the rotors which grooves have different, corresponding, cross-sectional shapes.

If FIGS. 1 and 2 are compared it will be seen that the two thrust heads E and F are in the position where the thrust head E, carried by the inner rotor C, is passing the thrust head F of the stationary member D. Both of the thrust heads E and F have near planar, slightly concave faces which lie parallel to each other in this position. The section 2—2 of FIG. 1 passes between and lies parallel to these two faces and that is why the face 14 of the thrust head F is shown in elevation in FIG. 2. The purpose of making the thrust head faces slightly concave is to allow for their clearance as they rotate past each other.

Each of the inserts G and H are arcuately shaped and are also provided with inclined and contoured surfaces 56 and 57, respectively. The ends 56*a* and 57*a*, respectively, of these surfaces 56 and 57 that lie adjacent to the pocket 13 lie in substantially the same plane that coincides with the outer edge of the face 14 of the thrust head F and the ends 56*b* and 57*b* of the surfaces at the opposite ends of the inserts G and H, respectively, feather into the adjacent surfaces of the semi-toroidal surfaces of the grooves 8 and 11 in the members C and D, respectively (see FIGS. 2, 3 and 8A).

FIGS. 3 and 4 show two transverse sectons 3—3 and 4—4 taken on FIG. 2 and illustrate how the inserts G and H are secured to the outer stationary member D by screws 17. The inserts may also be otherwise secured to the member D and project into the semi-toroidal groove 8 and have a sliding and nearly fluid-tight contact therewith. As will be explained in greater detail hereinafter, the shape of the arcuate and contoured surfaces 56 and 57 in the inserts G and H is such that as the thrust head E rotates on an axis that is radial to the axis of rotation of the inner member C the thrust head always has some portions of its hemispherical surface making a nearly fluid-tight sliding contact with the contoured surfaces 46 and 57 of the inserts G and H, respectively, as the inner rotor C carries the thrust head E around the toroidal chamber through one complete revolution of the rotor C. In other embodiments the thrust heads can be rotated on axes which are not radial to the common axis.

Before describing how the two thrust heads E and F are rotated on their axes, it is best to refer to FIGS. 8A to 8D, inclusive, to show the several positions of the inner rotor C with respect to the outer stationary member D as the inner rotor C makes one revolution and the thrust heads E and F are rotated on their radial axes through one complete rotation. FIG. 8A is an arcuate vertical section taken along the arcuate line 8A—8A in FIG. 2 and looking in the direction of the arrows, this arcuate section line coincides with the outer circular surface 7 of the inner rotating member C and the inner circular surface wall 10 of the outer stationary member D.

Since the thrust head F is carried by the stationary outer member D, the thrust head will not move laterally from its position shown in FIG. 8A but instead will merely be rotated about its radial axis one complete revolution for each complete revolution of the inner rotor C as will be hereinafter described. Also, inasmuch as the inserts G and H are disposed on opposite sides of the thrust head F and form the pocket 13, these inserts must remain stationary since they are secured to the outer stationary member D by the screws 17 and they extend over the adjacent portions of the semi-toroidal groove 8 of the inner rotor C. The screws 17 are shown by dot-dash lines in FIGS. 8A to 8D, inclusive, because they secure the inserts G to H to the stationary outer member D and not to the inner rotating member C.

FIGS. 8A to 8D, inclusive, also show two additional arcuately-shaped inserts J and K arranged on each side of the thrust head E and forming a pocket 18 in which

the thrust head E can rotate. These two inserts J and K are secured to the inner rotor C by screws **19,** or other suitable fastening means. The inserts J and K have contoured surfaces **54** and **55** extending into the semi-toroidal groove **11** of the stationary outer member D in the same manner as already described for the inserts H and G that are secured to the stationary member D and have portions projecting into the semi-toroidal groove **8** of the rotary inner member C.

It will now be described how the two thrust heads E and F are rotated on radially extending axes so that each thrust head will make a complete rotation on its axis while the inner rotary member C makes one complete revolution. A gear mechanism is arranged so that at the moment the thrust head E, carried by the inner rotating member C, passes the other thrust head F, rotatably carried by the outer stationary member D, both of the thrust heads E and F will have their faces lying generally parallel to the same plane in which the axes of the two thrust heads lie. FIGS. **1, 2** and **8**A illustrate the positions of the two thrust heads at the moment the thrust head E moves past the thrust head F.

Referring to FIG. **1,** it will be seen that the thrust head E has an integral and radially extending axle **20** that projects inwardly toward the axis of the inner rotary member C, and extends past this axis. As mentioned above, in other embodiments of the invention the axis of rotation of the thrust head does not extend radially from the common axis of the inner and outer rotors. The axis for the axle **20** intersects the axis of the rotary member C and the end of the axle **20** that extends beyond this point of intersection of the two axes has a gear L keyed thereto. The gear L meshes with a stationary gear M of equal diameter. It will be seen from FIG. **1** that the stationary gear M is rigidly connected to a tublar member **21** whose axis intersects the axis for the axle **20** of the thrust head E. The tubular member **21** is integral with the housing A. Therefore, as the inner rotary member C makes one complete revolution, the radially extending axle **20** will cause the gear L to travel one revolution around the stationary gear M of equal diameter to the gear L, and this will cause the axle **20** and its thrust head E to make one complete rotation about the axis of the axle **20.** What causes the inner rotatable member C to rotate will be explained hereinafter.

The outer stationary member D rotatably carries an axle **22** (see FIG. **1**) that is integral with the thrust head F and extends outwardly therefrom, the rotational axis of the axle **22** lying flush with the near planar face of the thrust head F and extending in a radial direction from the common axis of the stationary, central, tubular member **21** to the cylindrical wall **3** for the housing A. The outer end of the thrust head axle **22** is journalled in the cylindrical wall **3** of the housing A. A large gear N is keyed to the axle **22** of the thrust head F and this gear meshes with another large gear P of a planetary transmission, as shown in FIG. **1.** One revolution of the gear P will rotate the gear N through two revolutions.

The gearing shown in FIG. **1** has a pair of gears **23** and **24** that are journalled in bearings **25** and **26,** respectively, and the bearings are carried by the rear face of the large gear P, and therefore the bearings will be carried around by the rotating gear P. The inner rotating member C has a gear **27,** integral therewith and meshing with the gears **23** and **24.** The diameter of the gear **27** is the same as the diameters of the gears **23** and **24.** It will further be noted that the interior of the stationary housing A has an integral gear **28** of the same diameter as the gears **23** and **24** and it meshes with these gears. Therefore, as the inner rotary member C is rotated in a manner hereinafter described, it will rotate the gear **27** at the same speed and cause the gears **23** and **24** to rotate the large gear P at one-half the speed. Therefore, the large gear P will rotate the smaller gear N at twice the speed of the gear P, thereby rotating the axle **22** for the thrust head F at the same speed as the axle **20** for the thrust head E. The two axles **20** and **22** will rotate their thrust heads E and F at the same speed in a counterclockwise rotation as indicated by the arcuate arrows when looking at FIG. **8**A.

The inner rotary member C is directly connected to a single output shaft Q. This output shaft is rotatbly received in the tubular member **21** (see FIG. **1**) and the inner portion of the shaft that projects beyond the stationary gear M is made non-circular at **29** and is received in a non-circular opening **30** provided in the inner rotary member C and positioned at the axis of the member C.

It will now be described how steam or a gas under pressure can be delivered to the rotary engine for rotating the inner rotating member C and also for rotating the output shaft Q that is directly connected to the member C. In FIG. **1** there is shown the central tubular portion **6** of the inner rotary member C provided with a hollow sleeve valve R. This valve R is shown in development in FIGS. **9** and **10** where the cylindrical hollow valve is illustrated as though it had been split longitudinally and flattened so that the triangular shape of the single valve opening **31** can be better seen. The opening **31** practically encircles the circumference of the tubular valve and it may be reinforced by a median strip **32** of uncut material as clearly shown in FIGS. **9** and **10.**

Referring to FIG. **1,** it will be seen that the valve opening **31** can be brought into registration with an intake port in the passage **33** provided in the inner rotor C of the rotary engine. This intake port of the passage **33** communicates with the toroidal passage formed by the two semi-toroidal grooves **8** and **11** in the inner rotary member C and the outer stationary member D, respectively (see also FIGS. **2** and **8**A). The entrance of the intake port of the passage **33** that lies adjacent to the tubular sleeve valve R is formed in the shape of a triangle whose apex **33***a* points in the opposite direction to the apex **31***a* of the valve opening **31** (see the diagrammatic drawing of the sleeve R and the inner rotatable member C in FIGS. **9** and **10**). The arrow **34** in these FIGS. indicates the direction of rotational movement of the inner member C with respect to the sleeve valve R. The member C encloses the sleeve valve R and for that reason FIGS. **9** and **10** show the member C disposed in front of the sleeve valve R.

The sleeve valve R can also be shifted in the direction of its length, and thus shifted in respect to the intake opening **33,** in the inner rotary member C and this movement is indicated by the double headed arrow **35** in the diagrammatic FIGS. **9** and **10** to show that the valve can be moved at right angles to the direction of the rotational movement of the member C. When the sleeve valve R is in the position shown in FIGS. **1** and **9,** the rotation of the inner member C will cause the widest part of the triangular intake port **33** in the mem-

ber C to first register with the widest part of the triangular opening **31** in the sleeve valve with the result that the greatest flow of steam or gas under pressure will move from the valve interior and pass into the intake port **33.** This will give the greatest starting impulse to the rotary engine as will presently be described. Then as the inner member C rotates so as to move in the direction of the arrow **34,** in FIGS. **9** and **10,** the portion of the intake opening **33** which is coincident with the opening **31** in the valve R will be restricted.

Means are provided for moving the sleeve valve R in the direction of its length for determining the length of time during which a portion of the area of the triangular opening **31** in the sleeve valve registers with a portion of the triangular intake opening **33** in the inner rotatable member C. FIG. **10** shows diagrammatically the sleeve valve R moved downwardly a slight distance in the direction of the arrow **35** with respect to the member C. When this adjustment is made the time during which a part of the triangular opening **33** in the member C registers with a part of the area of the triangular opening **31** in the valve R is decreased from the duration of this registration as shown in FIG. **9.** When the valve R is in the axial position shown in FIG. **10,** the common registration between the openings **33** and **31** will be cut-off when the rotor C has turned such that the shortest edge (i.e., the right angle edge) of the triangular opening **33** is aligned approximately midway between the median strip **32** and the apex **31***a* of the opening **31.** With the valve sleeve in the position shown in FIG. **9,** this same cut-off takes place when the short edge of the opening **33** is aligned with the apex **31***a* of the opening **31.** This represents a longer portion of the rotary cycle.

In general, the source of expansion fluid is not regulated to maintain a constant pressure so that as the coincident area between the openings **31** and **33** is decreased the expandable fluid pressure at the source also increases. For example, if the source of fluid is a steam boiler and the heat source is constant, the steam pressure will increase when the valve opening area becomes restricted. This effect has the result that the steam flows through the valve at a higher rate and pressure. Thus, while axially moving the sleeve valve R does control the total volume of expansion fluid delivered to the engine, it primarily controls the duration of the pulse of expandible fluid and consequently the efficiency and power of the engine.

In FIGS. **1, 5, 6** and **7,** a novel mechanism is illustrated for moving the sleeve valve R in the direction of its length. A large disc S is positioned on the underside of the base member B and has a central opening **36** through which an enlarged cylindrical portion **37** extends. It will be described further in this specification how this disc S functions as a timing advance mechanism. FIGS. **1** and **5** show the disc S provided with a plurality of arcuate shouldered slots **38** that receive cap screws **39.** These cap screws are threaded into the base B and permit the disc to be rotated into various angular positions within the limits determined by the lengths of the arcuate slots. FIGS. **5** and **7** show the disc S provided with a radial and outwardly extending handle **40** by means of which the operator may rotate the disc about its center for controlling the timing as to when the compressed gas or steam enters the intake port **33** in the inner rotor C. This action is somewhat analogous to the control in an internal combustion engine which advances or retards the firing of the sparkplugs. Before fully describing how the timer disc S operates, the description will continue as to how the axial movement of the sleeve valve R is controlled.

A sector-shaped throttle member T (see FIGS. **1, 5,** 6 and **7**) for moving the sleeve valve R in the direction of its length, is pivotally attached by a cap screw **41** to the underside of the disc S. The throttle member T has an arcuately-shaped shouldered slot **42** whose center is at the axis of the cap screw **41.** Another cap screw **43** is slidably received in the arcuate slot **42** and the slot and cap screw limit the angle through which the throttle member T can be swung. A radially outwardly extending handle **44** is attached to an arcuate edge **45** of the throttle member T (see FIGS. **5** and **7**).

Again referring to FIGS. **1, 5, 6** and **7,** the throttle member T has an arcuate slot **46** therein that opens onto the edge **47** of the member T (note especially FIG. **5**). This arcuate slot **46** slidably receives the enlarged cylindrical portion **37** of the sleeve valve R, and FIGS. **1, 5** and **7** show the enlarged cylindrical portion **37** provided with two inclined grooves **48** and **49** disposed diametrically apart. The arcuate side walls of the slot **46** in the throttle member T are provided with inwardly extending and inclined ribs **50** and **51** that are slidably received in the diametrically opposed grooves **48** and **49,** respectively, in the enlarged cylindrical portion **37** of the sleeve valve R. FIG. **6** is a section taken along the arcuate section line **6—6** of FIG. **5** and illustrates how the arcuate rib **51** is inclined so that swinging the handle **44** of the throttle member T about its pivot point **41** will move the sleeve valve R along its length, with the particular direction depending upon in which direction the throttle handle **44** is swung. FIG. **1** shows the throttle member T in a position where the sleeve valve R is in its innermost position. Shifting the throttle handle **44** which controls the swinging of the throttle member T moves the sleeve valve R along its axis in the desired direction.

It is best to now set forth the path taken by the steam or gases under pressure from the inlet end **52** of the sleeve valve R to the exhaust pipe **53** (see FIG. **1**) and to describe how the thrust heads E and F are rotated on their own axles **20** and **22,** respectively. FIGS. **1, 2** and **8A** show the positions of the thrust heads E and F at the moment the thrust head E moves past the thrust head F which is rotating about its stationary axis. The steam or compressed gas enters the inlet **52** of the sleeve valve R from a source (not shown) and passes through the valve opening **31** and into the intake passageway **33** provided in the inner rotatable member C and in the insert J.

FIG. **8A** shows the intake passage **33** emptying into the toroidal chamber formed by the two semi-toroidal grooves **8** and **11** provided in the inner rotary member C and the outer stationary member D, respectively. The outer surface of the inner rotary member C is shown in elevation in FIG. **8A** because the arcuate section line **8A—8A** in FIG. **2** from which FIG. **8A** is taken, coincides with the circumference of the outer portion **7.** The inserts J and K in FIG. **8A** are shown connected to the inner rotatable member C by the screws **19** and these inserts have portions projecting into the semi-toroidal groove **11.** Both inserts are contoured at **54** and **55,** respectively. The contours start from opposite sides of the pocket **18** and gradually growing deeper until they terminate in a feathered edge

that leads into, and substantially lies flush with the surfaces of the semi-toroidal grooves **8** and **11.** The shape of these contoured surfaces **54** and **55** are engineered to make a nearly fluid-tight seal with the rotating thrust head F as the inner member C rotates with respect to the stationary member D. The inlet passage **33** for the steam or gas under pressure can communicate with the interior of the toroidal chamber through the insert J, as shown in FIG. **8**A, or adjacent to the insert. In like manner the other two inserts G and H, which are attached to the stationary outer member D, have contoured surfaces **56** and **57,** respectively, in FIG. **8**A which gradually grow deeper from the pocket **13** until they terminate in feathered edges that are substantially flush with the surfaces of the semi-toroidal grooves **8** and **11.** These contoured surfaces make a nearly fluid-tight seal with the rotating thrust head E as the inner member C rotates with respect to the stationary member D and carries the thrust head E with it, this thrust head also rotating on its own axle **20** through one revolution each time the member C rotates through one revolution.

The rotating member C should preferably never be stopped in the position shown in FIG. **8**A because this is a "dead center" position and the inner member C will not thereafter rotate. The dead center position is shown merely to illustrate the position of the two rotating thrust heads E and F at the moment the rotating inner member C carries its thrust head E past the thrust head F. In FIG. **8**B, the inner rotating member C has moved to the left through an angle of about 90° and both of the thrust heads E and F have likewise rotated on their radial axes through angles of 90° in the direction of their arcuate arrows. Although the thrust head F rotates about a stationary radial axis because it is carried by the stationary outer member D, the thrust head F is shown in FIG. **8**B moved to the right rather than in the center as in FIG. **8**A. This has been done in order to show the other thrust head E in the same FIG. **8**B even though the inner rotary member C has advanced through an arc of 90°. Arrows **58** and **59** show how the expanding steam or gases under pressure direct a driving force against the faces **60** and **14** of the thrust head E and F, respectively. The thrust head F cannot rotate the stationary member D in which it is mounted and therefore the expanding steam or compressed gas will force the thrust head E to the left in FIG. **8**B. This is likened to the combined intake and power stroke of the rotary engine.

FIG. **8**C shows diagrammatically certain parts of the rotary engine where the inner rotary member C has advanced through an arc of 270° from the position shown in FIG. **8**A. Again, the thrust head F is shown at the left hand side of FIG. **8**C although this thrust head rotates about a stationary and radially extending axis. FIG. **8**C shows the thrust head E at the right hand side of the FIGURE The arrows **62** and **63** which point away from the faces **60** and **14** of the thrust heads E and F, respectively, in FIG. **8**C, indicate the exhaust portion of the cycle for a single revolution of the inner member C. The exhaust gases that are trapped between the two thrust heads E and F will be forced out through an exhaust port **64** provided in the insert G. FIG. **1** shows the exhaust port **64** in the outer stationary member D communicating with the interior of the housing A where the exhaust gases enter. The stationary housing A has an exhaust port **65** that registers with an annular passage **66** provided in the base member B and the base member has an exhaust port **67** placing the annular passage **66** in communication with the exhaust pipe **53.**

FIG. **8**D shows diagrammatically the same elements as in FIG. **8**C but with the rotary member C advanced through an arc of 315° from the position shown in FIG. **8**A.

The energy of the rotary engine is controlled by moving the sleeve valve R in the direction of its length because, as explained above, this alters the time during the rotary cycle in which a portion of the area of the triangular opening **31** in the valve registers with a portion of the triangular inlet opening **33** in the inner rotating rotor C (see FIGS. **9** and **10**). This, in turn, controls both the quantity of steam or gas under pressure that enters the intake **33** during the rotation of the rotor C but also the efficiency and power of the engine since the source of expandible fluid is not maintained constant but instead tends to increase in pressure as the coincident opening area between the valve and the rotor is restricted. The throttle handle **44** and sector plate T can be swung to move the sleeve valve R in the direction of its length by means of the inclined ribs **50** and **51** in the arcuate slot **46** (see FIGS. **5** and **6**).

With reference to FIG. **1,** it can be seen that as the inner rotor C increases its speed of rotation the time in which the "pulse" of expandible fluid must travel from the valve opening **31** to the toroidal chamber opening of the passage **33** decreases for any given setting of the valve sleeve R. Since the speed of travel of this pulse is only variable within certain limits by controlling various factors at the source, it becomes desirable to introduce the fluid pulse earlier in the rotational cycle to allow it a greater time to travel the length of this passage. This process is very roughly analogous to advancing the firing of the sparkplugs in an internal combustion engine as the engine increases in speed.

The timing factor is controlled by twisting the sleeve valve R about its longitudinal axis. Referring to FIG. **5,** the timer disc S can be swung by the handle **40** about the axis of the sleeve valve R, as a center. When the timer disc S is rotated through a desired arc, limited by the lengths of the arcuate slots **38,** the pivot bolt **41** for the sector plate T will be swung through a similar arc. This will cause the inwardly extending and inclined ribs **50** and **51** of the arcuate slot **46** to act on the diametrically opposed grooves **48** and **49** in the sleeve valve R and rotate it about its own axis through the same degree of arc as taken by the rotated timing disc S. The result is that the triangular opening **30** in the sleeve valve R (see FIGS. **9** and **10**) will be rotated through the same arc as the timing discs and will either register earlier or later in the rotary cycle with the inlet port **33** in the inner rotor C, depending upon in which direction the operator has moved the timer handle **40** in FIG. **5.** The steam or gas under pressure will therefore enter the inlet port **33** either earlier or later during any given single revolution of the inner rotor C. In this way the timer disc S acts as an "advance" or a "retard" member for the flow of steam or gas as it flows from the sleeve R through this valve opening **31** and into the intake opening **33** of the rotor C.

In FIG. **11,** a slightly modified form of the rotary engine is shown. Parts of the engine in FIG. **11** that are similar to corresponding parts in the form of rotary engine shown in FIG. **1** are given like character letters or reference numerals. The housing A is free to rotate be-

cause the bolt **1**, shown in FIG. **1** for holding the housing A stationary in that FIGURE is not used in the modified form shown in FIG. **11**. The inner rotor C and the outer rotor D are identical in both forms of the rotary engine except that in FIG. **11** the outer rotor D will rotate with the housing A and in an opposite direction to the rotation of the inner rotor C. The thrust heads E and F are identical in both forms and so is the gearing.

The main difference between the two forms in that the rotatable housing A is directly connected to a hollow shaft U that encloses a portion of the shaft Q which, in turn, is directly connected to the inner rotor C through the non-circular inner end **29** of the shaft that is received in the non-circular opening **30** in the rotor C. The two shafts Q and U are rotated in opposite directions by the rotors C and D, respectively, during the operation of the engine and they may be used for any purpose desired. The shaft Q is shown in FIG. **11** as rotating a propeller V and the shaft U as rotating a propeller W. Such a relation of two propellers arranged in tandem and being rotated in opposite directions is ideal for propelling a boat or ship through the water because it is well known that more force for moving a vessel through the water, and at a faster speed, results when two oppositely rotating propellers with reverse pitch blades are arranged in tandem and are rotated about a common axis. Because the rotation of the thrust heads E and F is controlled by the relative movement between the rotary members C and D, with both rotary members C and D rotating in opposite directs at the same speeds, the thrust heads E and F will turn through two revolutions for each complete revolution of the rotary members C and D, i.e., the engine will go through two expansion cycles for each complete revolution of the rotary members C and D.

The only other difference between the two rotary engines shown in FIGS. **1** and **11** lies in a sleeve valve R', shown also in development in FIGS. **12** and **13.** The valve R' is provided with two triangular openings **75** and **76** that successively register with the inlet opening **33** in the inner rotating rotor C during the two expansion cycles mentioned above. The direction of rotation of the inner rotor C is indicated by the arrow **34** in FIGS. **12** and **13,** and the longitudinal movement of the sleeve valve R' is indicated by the arrow **35.** Such an arrangement of ports **75** and **76** in the sleeve valve R', results in two impulses being given to the rotors C and D for each revolution of the rotors in opposite directions.

The term "expansion fluid" is used generically to broadly include steam or gases under pressure.

Although the thrust heads have been described above as being hemispherical in shape, it should be apparent that it is only necessary that their shape conform to the cross-section of the toroidal groove. Thus, in some other embodiments having toroidal grooves of different cross-sectional shapes, they may be ellipsoidal, almond-shaped, or hemi-cylindrical. Furthermore, in these other embodiments the axis of rotation of the thrust heads need not necessarily be radially extending from the common axis of rotation of the rotors.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, it is understood that certain changes and modifications may be practiced within the spirit of the invention as limited only by the scope of the appended claims.

What is claimed is:

1. A rotary engine comprising:

a. a pair of inner and outer members, at least one of which is rotatable with respect to the other about a common axis;

b. the inner member having an outer circular periphery and the outer member having an inner circular periphery that slidably contacts the outer periphery of the inner member, the inner member having a semi-toroidal groove formed in its outer periphery and the outer member having a complementary semi-toroidal groove formed in its inner periphery and facing the semi-toroidal groove in the inner member to form a complete toroidal chamber therewith;

c. a first thrust head carried by the inner member and receivable in the toroidal chamber, the first thrust head having a shaft which is rotatable in the inner member;

d. a second thrust head carried by the outer member and receivable in the toroidal chamber, the second thrust head having a shaft which is rotatable in the outer member;

e. a first pair of arcuate-shaped inserts, one insert being disposed on each side of the first thrust head to form a first pocket and each being secured to the inner member, the inserts having contoured surfaces extending from the first pocket and terminating in feathered edges that merge into the surface of the toroidal chamber, the first thrust head being rotatable receivable in the first pocket;

f. a second pair of arcuate-shaped inserts, one insert being diposed on each side of the second thrust head to form a second pocket and each being secured to the outer member, the second pair of inserts having contoured surfaces extending from the second pocket and terminating in feathered edges that merge into the surface of the toroidal chamber, the second thrust head being rotatably receivable in the second pocket;

g. means for operatively connecting the inner and outer members together so that at least one of them is rotatable with respect to the other and for rotating the thrust heads so as to continuously close the cross-sectional area of the toroidal chamber and the restricted cross-sectional area caused by the inserts, the first and second thrust heads being rotated on their own axes so that they will pass each other during each revolution of the inner member relative to the outer member;

h. means for delivering an expansion fluid into the chamber portion lying between the first and second thrust heads for moving them apart;

i. means for exhausting the expansion fluid from that portion of the toroidal chamber lying between the first and second thrust heads in the direction in whcih they are moving relatively toward each other; and

j. output shaft means operatively connected to produce a driving torque from the relative rotational movement between the inner and outer members.

2. The combination as recited in claim **1** further comprising means for holding one of the inner and outer members from rotating and an output shaft connected to the other of the inner and outer members whereby the output shaft will be rotated with greater energy.

3. The combination as recited in claim **1** wherein:

a. each thrust head has both hemispherical and near planar surfaces;

b. the first and second pockets formed by the first and second pairs of arcuate-shaped inserts, respectively, are hemispherical in shape;

c. the means for rotating the inner and outer members relative to each other and for rotating the first and second thrust heads also cause them to be entirely received within their first and second hemispherical pockets, respectively, at the moment the first and second thrust heads pass each other, the near planar surfaces of both the first and second thrust heads lying parallel to each other at the moment of passing.

4. The combination as recited in claim **3** wherein the shafts for the first and second thrust heads extend radially with respect to the common rotational axis of the inner and outer members.

5. The combination as recited in claim **1** wherein the means for delivering an expansion fluid into the toroidal chamber comprises a sleeve valve for controlling both the duration and the time of introduction with respect to the rotational positions of the inner and outer members of the delivery of the expansion fluid into the toroidal chamber whereby both the energy of the output shaft and the operating efficiency of the rotary engine are controlled.

6. The combination as recited in claim **5** wherein:

a. the inner member is rotatable and has an inlet port that communicates with the toroidal chamber and the sleeve valve is hollow and is axially aligned with the common axis of the inner and outer members, the valve receiving the expansion fluid from an external source and having an outlet port selectively registrable with the inner member inlet port;

b. the valve outlet port and the inner member inlet port each having openings which taper in opposite directions and which are periodically in registration with each other as the inner member rotates;

c. and further including means for moving the sleeve valve in the direction of its length to reposition the degree of registration between the sleeve valve outlet port with respect to the inner member inlet port whereby the time during which the expansion fluid enters the inlet port is varied to thereby control the energy of the output shaft and the efficiency of the engine.

7. The combination as recited in claim **6** wherein:

a. the sleeve valve is rotatable about its longitudinal axis to control the timing of the introduction of the expansion fluid to the toroidal chamber with respect to the rotational position of the inner member; and

b. the means for moving the sleeve valve includes means for selectively twisting the sleeve valve about its longitudinal axis.

8. The combination as recited in claim **7** wherein

a. the sleeve-valve-moving-means includes a timer member selectively rotatable about the common axis for the inner and outer members and having a central opening through which a portion of the sleeve valve extends, the timer member having a handle for selectively moving the timer member through a desired arc;

b. the sleeve-valve-moving means also includes a sector-shaped member pivoted off center to the timer member and having an arcuate slot for receiving a portion of the sleeve valve, the center of curvature of the arcuate slot coinciding with the axis of the pivot interconnecting the sector-shaped member with the timer member; and

c. the outer cylindrical surface of the sleeve valve portion received in the arcuate slot has diametrically opposed grooves and the arcuate-shaped slot in the sector-shaped member has inclined and inwardly extending ribs that are slidably received in the diametrically opposed grooves, the sector-shaped member further having a handle for rotating the sector-shaped member about its pivotal connection with the timer member; whereby the sleeve valve is selectively movable in the desired direction along its length by rotating the sector-shaped member handle and is selectively rotatable about its longitudinal axis by rotating the timer member handle.

9. The combination as recited in claim **1** wherein the means for operatively connecting the inner and outer members together includes gearing that causes the inner and outer members to rotate in opposite directions and in synchrony with each other.

10. The combination as recited in claim **9** wherein the inner member is operatively connected to a first output shaft and a second, hollow tubular output shaft is connected to the outer member and encloses a portion of the first output shaft and rotates in an opposite direction to that of the first output shaft.

11. The combination as recited in claim **5** wherein the sleeve valve has at least two outlet ports.

12. A rotary engine comprising:

a. a pair of first and second rotor members, at least the first of which is rotatable with respect to the other about a common axis;

b. the first rotor member having a circular periphery and the second rotor member having a circular periphery that slidably contacts the circular periphery of the first rotor member, the first rotor member having a semi-toroidal groove formed in its periphery and the second rotor member having a complementary semi-toroidal groove formed in its periphery and facing the semi-toroidal groove in the first rotor member to form a complete toroidal chamber therewith;

c. a first, rotatable thrust head carried by the first rotor member and receivable in the toroidal chamber;

d. a second, rotatable thrust head carried by the second rotor member and receivable in the toroidal chamber;

e. a first pair of arcuate-shaped inserts, one insert being disposed on each side of the first thrust head to form a first pocket and each being secured to the first rotor member, the inserts having contoured surfaces extending from the first pocket and terminating in feathered edges that merge into the surface of the toroidal chamber, the first thrust head being rotatably receivable in the first pocket;

f. a second pair of arcuate-shaped inserts, one insert being disposed on each side of the second thrust head to form a second pocket and each being secured to the second rotor member, the second pair of inserts having contoured surfaces extending from the second pocket and terminating in feathered edges that merge into the surface of the toroi-

dal chamber, the second thrust head being rotatably receivable in the second pocket;

g. means for operatively connecting the first and second rotor members together and for rotating the thrust heads so as to continuously close the cross-sectional area of the toroidal chamber and the restricted cross-sectional area caused by the inserts, the first and second thrust heads being rotated on their own axes so that they will pass each other during each revolution of the first rotor member relative to the second rotor member;

h. means for delivering an expansion fluid into the toroidal chamber including a hollow sleeve valve for controlling both the duration and the time of introduction with respect to the rotational positions of the first and second rotor members of the delivery of expansion fluid into the toroidal chamber;

i. the first member having an inlet port that communicates with the toroidal chamber, the sleeve valve being axially aligned with the common axis of the first and second rotor members, the valve receiving the expansion fluid from an external source and having an outlet port selectively registrable with the first member inlet port;

j. the valve outlet port and the first rotor member inlet port each having openings which taper in opposite directions and which are periodically in registration with each other as the first rotor rotates;

k. and further including means for moving the sleeve valve in the direction of its length to reposition the degree of registration between the sleeve valve outlet port with respect to the first rotor member inlet port whereby the time during which the expansion fluid enters the inlet port is varied to thereby control the energy of the output and the efficiency of the engine;

l. means for exhausting the expansion fluid from that portion of the toroidal chamber lying between the first and second thrust heads in the direction in which they are moving relatively toward each other; and

m. output shaft means operatively connected to produce a driving torque from the relative rotational movement between the first and second rotor members.

13. The combination as recited in claim **12** wherein:

a. the sleeve valve is rotatable about its longitudinal axis to control the timing of the introduction of the expansion fluid to the toroidal chamber with respect to the rotational position of the first rotor member; and

b. the means for moving the sleeve valve includes means for selectively twisting the sleeve valve about its longitudinal axis.

14. The combination as recited in claim **13** wherein

a. the sleeve-valve-moving-means includes a selectively rotatable timer member having a central opening through which a portion of the sleeve valve extends, the timer member having a handle for selectively moving the timer member through a desired arc;

b. the sleeve-valve-moving means also includes a sector-shaped member pivoted off center to the timer member and having an arcuate slot for receiving a portion of the sleeve valve, the center of curvature of the arcuate slot coinciding with the axis of the pivot interconnecting the sector-shaped member with the timer member; and

c. the outer cylindrical surface of the sleeve valve portion received in the arcuate slot has diametrically opposed grooves and the arcuate-shaped slot in the sector-shaped member has inclined and inwardly extending ribs that are slidably received in the diametrically opposed grooves, the sector-shaped member further having a handle for rotating the sector-shaped member about its pivotal connection with the timer member; whereby the sleeve valve is selectively movable in the desired direction along its length by rotating the sector-shaped member handle and is selectively rotatable about its longitudinal axis by rotating the timer member handle.

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