

[54] **ROTARY ENGINE**

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[22] Filed: **Jan. 11, 1973**

[21] Appl. No.: **322,635**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 45,063, June 10, 1970.

[52] U.S. Cl. **60/525**

[51] Int. Cl. **F02g 1/04**

[58] Field of Search **60/24, 525**

[56] **References Cited**

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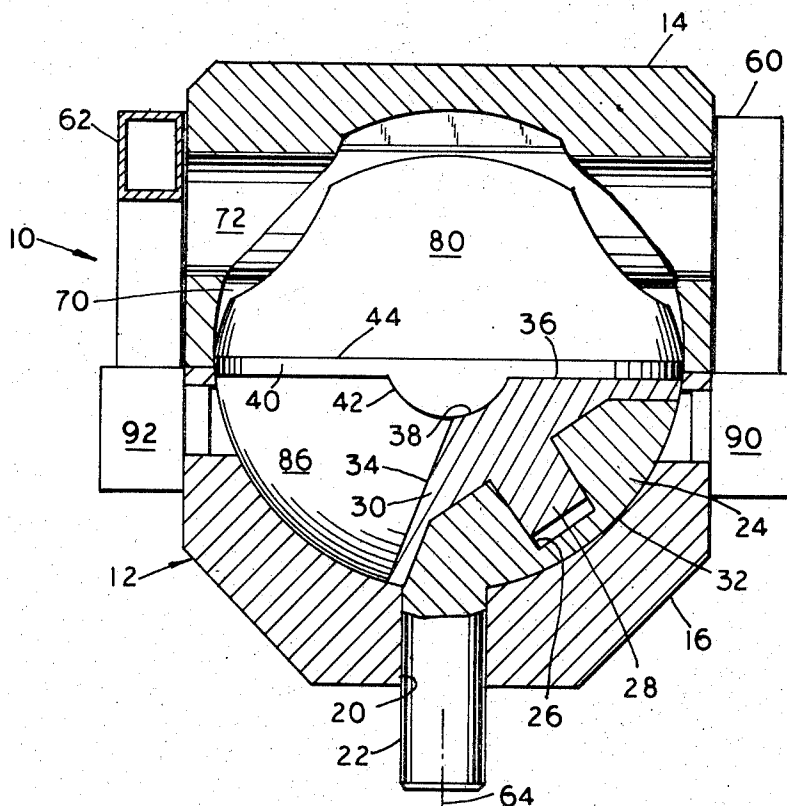
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[57] **ABSTRACT**

There is disclosed a rotary engine providing two cooperating Stirling cycle systems, the engine including a spherical cavity divided by a pivotal disk into two hemispherical sections one of which is divided into two chambers and is in heat exchange relationship with a heat source, a conduit connects each of the two hot chambers to the cold section. A spherical wedge is rotatably mounted in the cold section and is drivingly connected to a crank shaft. Expanding fluids alternating in the hot sections cause the disk to pivot and the wedge to rotate and pivot effecting rotation of the crank shaft.

13 Claims, 15 Drawing Figures



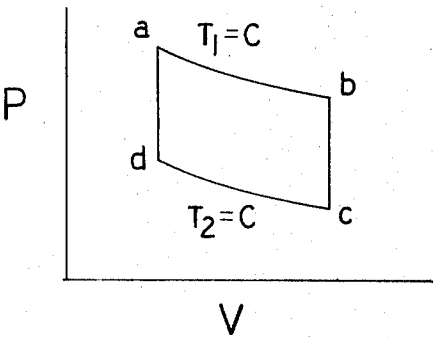


FIG. 1

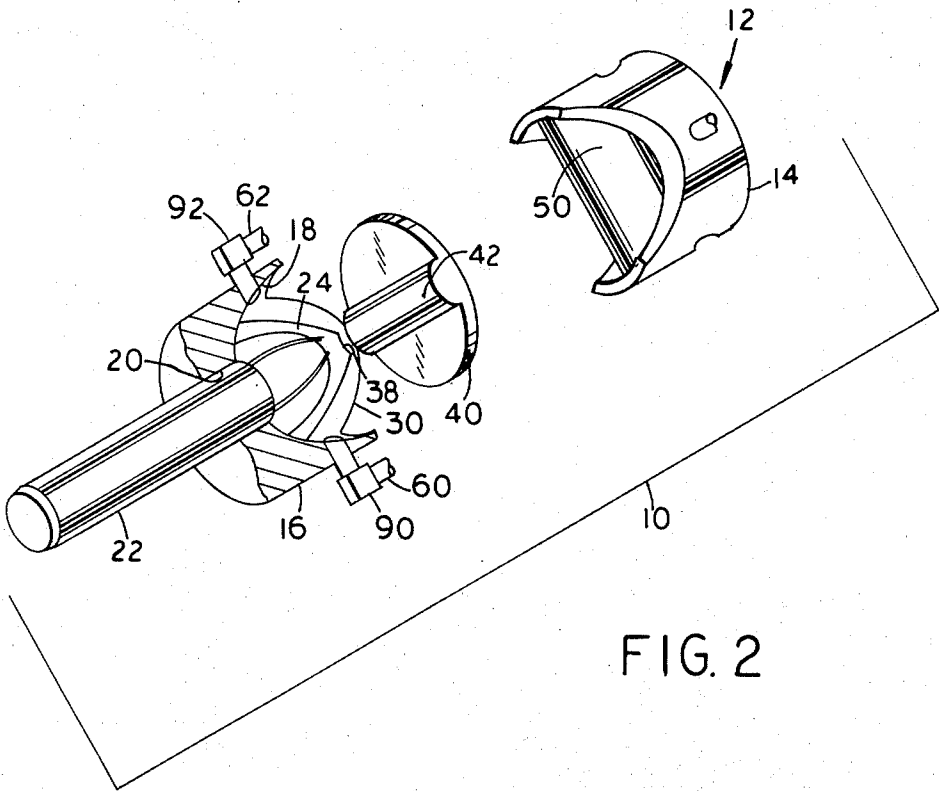


FIG. 2

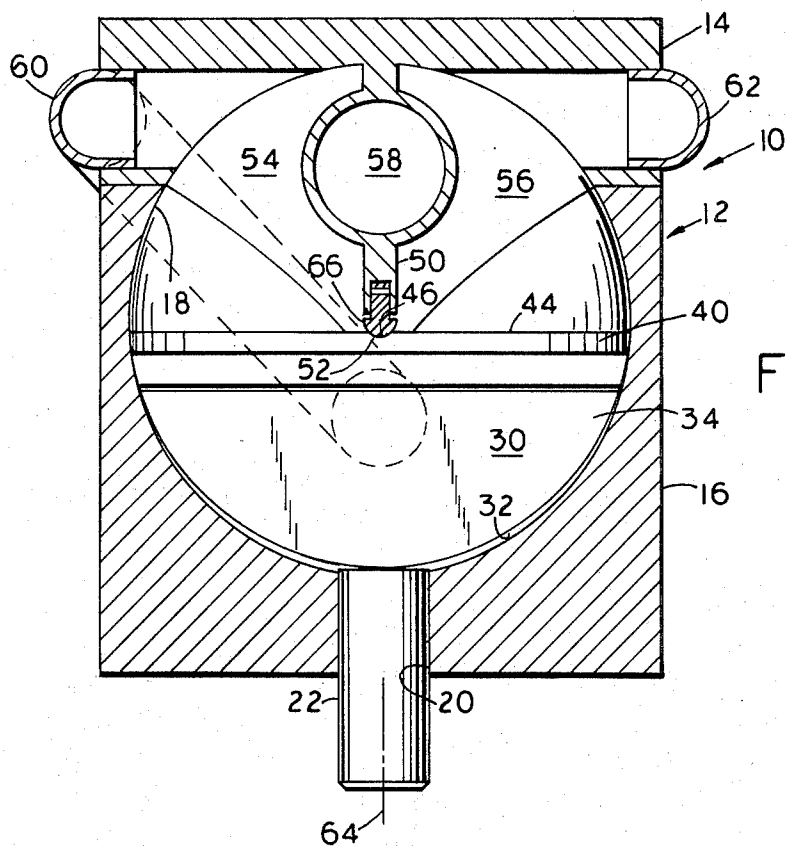


FIG. 3

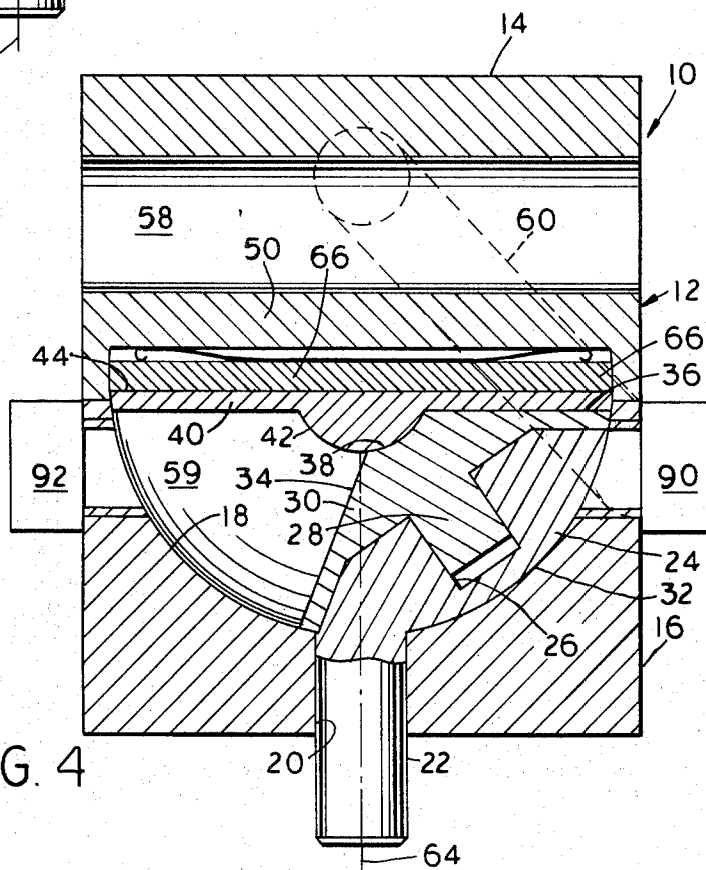


FIG. 4

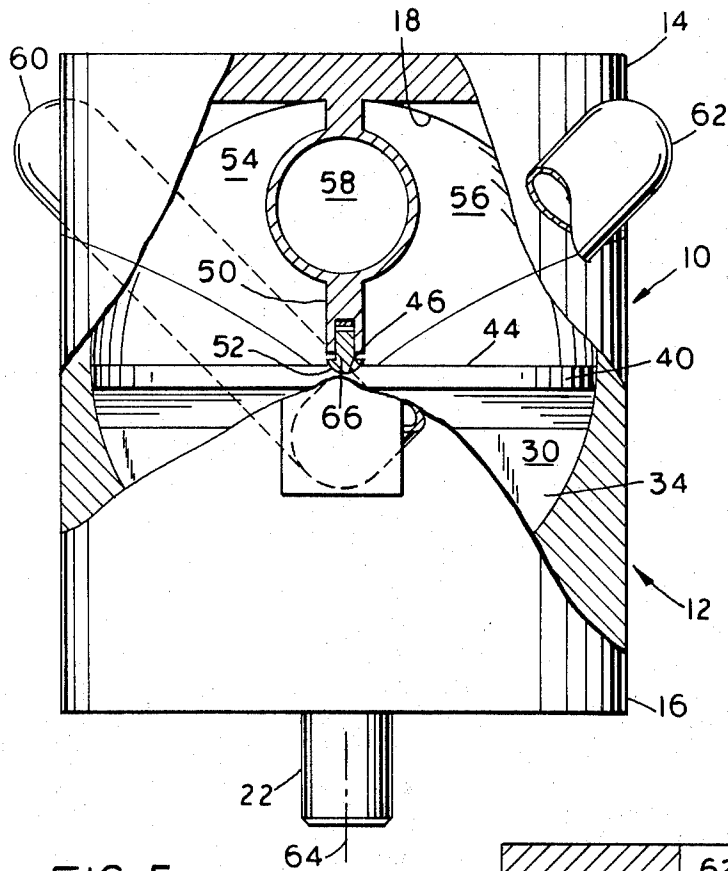


FIG. 5

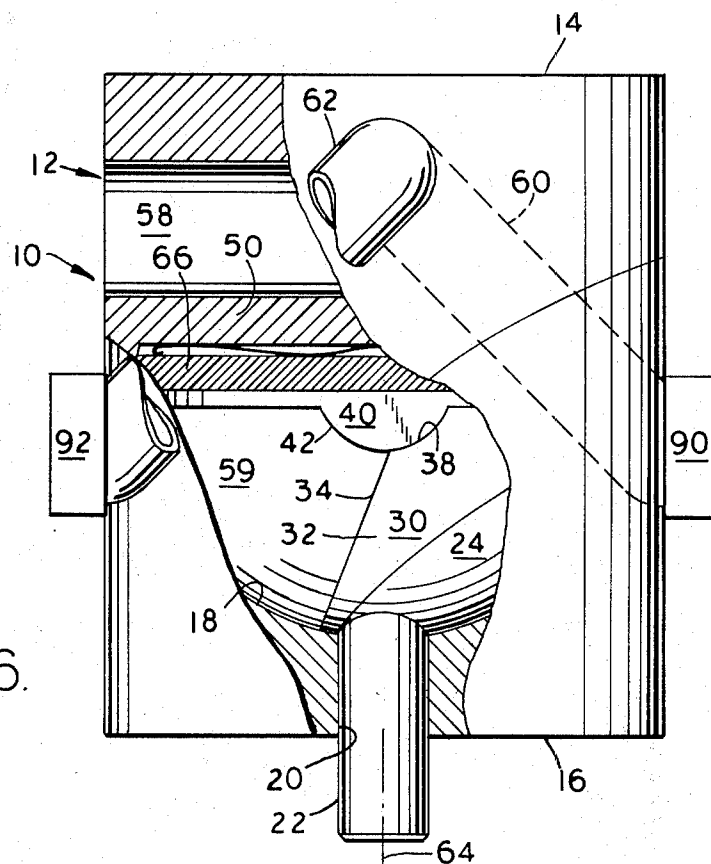
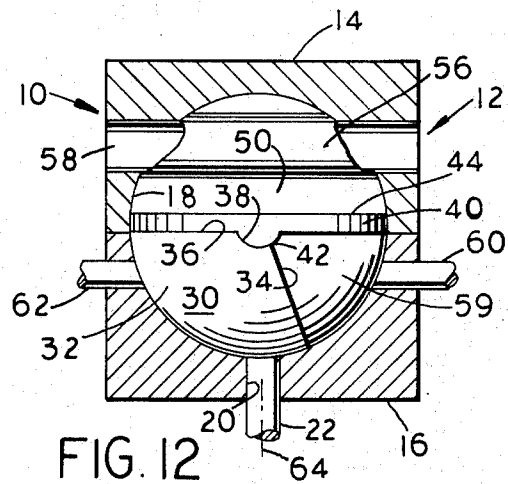
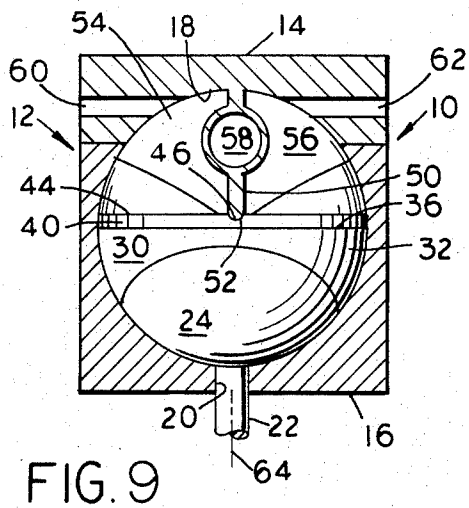
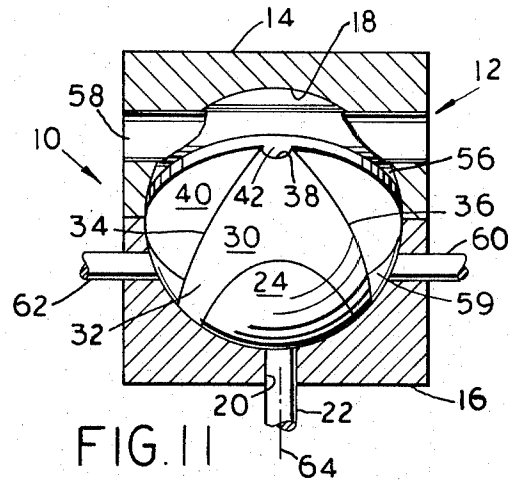
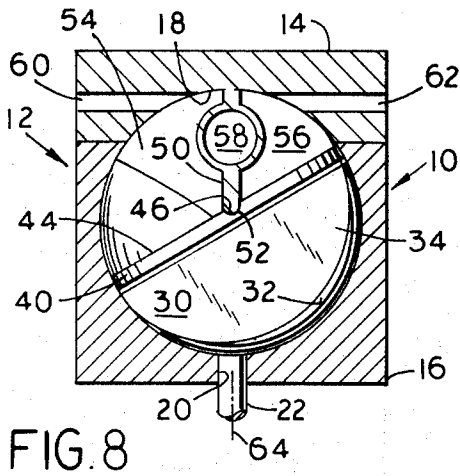
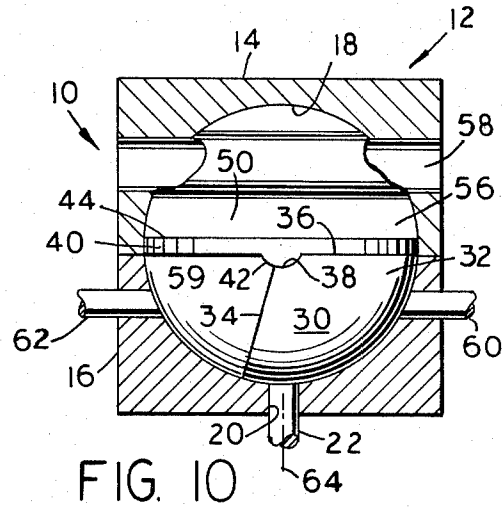
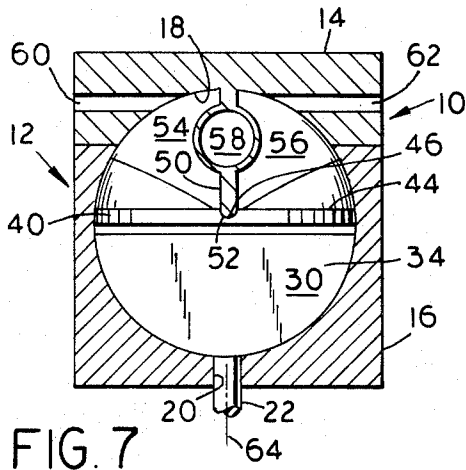


FIG. 6.



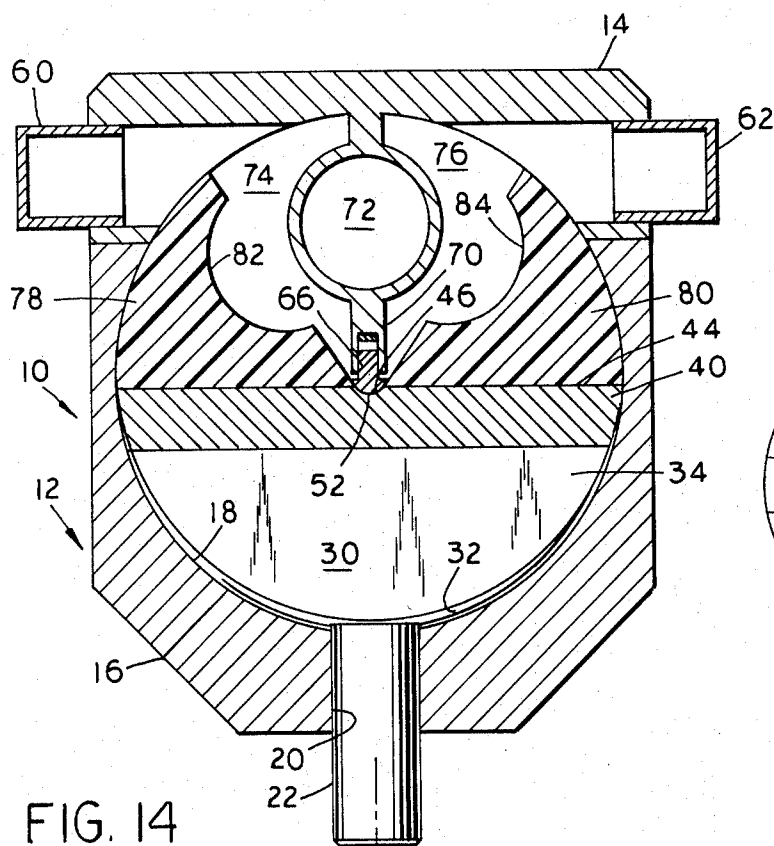
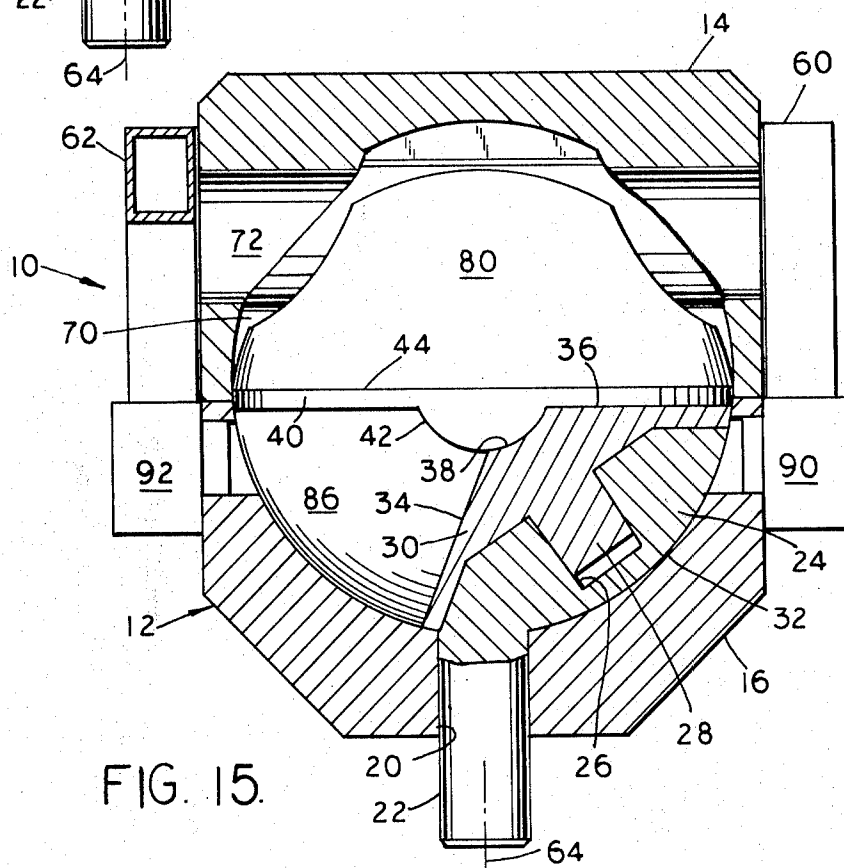
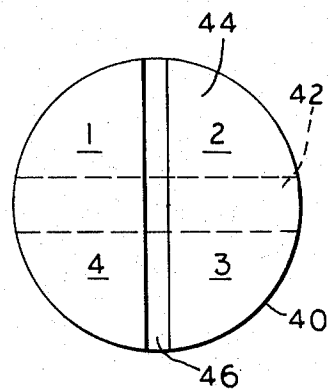


FIG. 13



ROTARY ENGINE

This is a continuation in part of U.S. patent application Ser. No. 45,063 filed June 10, 1970 entitled Spherical Pump System.

This invention relates to rotary engines and, more particularly, to such an engine incorporating the principles of the Stirling cycle.

Many different internal heating rotary engines are known; however, because of major sealing and other problems the practical use and acceptance of many rotary systems has been retarded. One of the primary advantages to a rotary engine over conventional reciprocating engines is the reduction in number of moving parts and, concomitantly, a reduction in maintenance and repairs and a simpler system. Other advantages include the elimination of the buffer space used in reciprocating Stirling cycle engines and piston rods and, therefore, a small volume for comparable output is required.

It is an objective of the improved rotary pumping system of this invention to provide a system which has high efficiency, a minimum of moving parts and reduced sealing problems.

It is another objective of this invention to provide a large volume rotary pump which can replace the conventional Roots blower in many applications.

BRIEF DESCRIPTION OF THE INVENTION

Briefly described, this invention, in one form, comprises in combination two cooperating Stirling cycle systems. The structure involves a substantially spherical cavity divided into two primary sections, one section being in heat exchange relationship with a heat source and, therefore, being considered as a hot section while the other section is considered the cold section of the heat engine. Rotatably supported within the cold section is a crank shaft which is drivingly connected to a spherical wedge capable of combined rotary and pivotal motion. A disk is pivotally supported in the spherical cavity. The apex of the wedge sealingly meets with one side of the disk along the disk's diameter.

The hot section of the heat engine is divided into two chambers, each chamber of which is connected through conduits to the cold section with the conduits entering the cold section at opposite sides. As can be seen only three moving parts, namely the disk, the spherical wedge and the crank shaft, are required.

Gases in the hot section are heated resulting in an increased pressure which, by virtue of the relative position of the wedge and disk, causes the disk to pivot and the wedge to rotate and pivot effecting rotation of the crank shaft. Pivoting of the disk effects increased volume in one half of the hot section and the cold section connected thereto and decreased volume in the other half of the hot section and cold section connected to it providing an expansion stroke for one section and a compression stroke for the other section. Upon completion of these strokes the operation of the sections reverse and expansion takes place in the half previously compressed resulting in continued rotation of the disk and wedge and, therefore, the crank shaft.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objectives and attendant advantages of this invention will be better understood from the detailed description below taken together with the drawings in which:

FIG. 1 is a P-V diagram illustrating a Stirling cycle with a perfect gas.

FIG. 2 is an exploded perspective view of a heat engine formed in accordance with the first embodiment of this invention.

FIG. 3 is a sectional view of the heat engine of FIG. 2.

FIG. 4 is a partial sectional view rotated 90° from the view of FIG. 3.

FIG. 5 is a partial sectional view illustrating the arrangement of conduits connecting the hot section to the cold section of the engine.

FIG. 6 is a partial sectional view illustrating the arrangement of conduits with the engine rotated 90° with respect to FIG. 5.

FIGS. 7, 8 and 9 are partial sectional views illustrating the positions of the disk and wedge during a 180° rotation of the crank shaft connected to the wedge.

FIGS. 10, 11 and 12 correspond to FIGS. 7, 8 and 9 respectively but illustrate the heat engine rotated 90°.

FIG. 13 is a top view of a disk used in the system of this invention.

FIG. 14 is a sectional view of a heat engine formed in accordance with the second embodiment of this invention.

FIG. 15 is a partial sectional view rotated 90° from the view of FIG. 14.

DETAILED DESCRIPTION OF THE INVENTION

Since this heat engine is designed around the well known Stirling cycle, before describing the system of this invention in detail, it might be helpful to briefly describe a Stirling cycle. With reference to the P-V diagram shown in FIG. 1, it can be seen that the Stirling cycle consists of the following processes with a system composed of a perfect gas. In process step *a-b* heat is transferred to the gas and work is transferred out at constant temperature T_1 (the expansion process); in process *b-c* temperature is reduced at constant volume by transferring heat out of the gas; in process *c-d* heat is rejected and work is transferred into the gas at constant temperature T_2 (compression); in process *d-a* temperature is raised at constant volume by transferring heat into the gas. If a regenerative arrangement is used so that the heat transferred out during the process *b-c* is returned reversibly during the process *d-a* there is no external heat transfer except at constant temperatures T_1 and T_2 .

Turning now to FIGS. 2, 3 and 4 the various elements forming the heat engine 10 of this invention can be seen. The engine 10 includes an engine body 12 formed of two mated sections 14, 16. The inner surface of the sections 14, 16 are such that when both sections are placed together a spherical cavity 18 is formed. One of the engine sections 16 is provided with a cylindrical aperture 20 which connects with the cavity 18 formed therein and which receives a rotatable cylindrical crank shaft 22. The crank shaft 22 terminates in an offset member 24 which may be best seen in FIG. 4. The offset member 24 is contoured on its outer surface to mate

with and ride on the wall of the spherical cavity 18. A recess 26 is provided on the inwardly facing surface of the offset member 24 to receive a radially extending projection 28 extending from a wedge 30. The wedge 30 is shaped on one surface 32 thereof to mate flush with and ride on the interior surface of the cavity 18. The other two faces 34, 36 include an angle between them greater than 90° but less than 180° . It has been found that 112° is a suitable angle. A groove 38 is provided along the length of the wedge 30 at its apex.

A disk 40 whose diameter is slightly less than the diameter of the spherical cavity 18 is located in the engine body section 16. The disk has a semi-cylindrical convex portion 42 along a diameter on one surface thereof, the radius of which is equal to that of the groove 38 in the wedge 30 thereby enabling the convex portion 42 to sealingly mate with the wedge 30. The opposite surface 44 of the disk 40 is provided with a radial concavity 46 aligned at right angles to the convex portion 42.

Engine section 14 is provided on the interior thereof with a partition 50 having a convex tip 52 complementarily formed to be received within the concavity 46 on the disk 40. The tip 52 extends below the center of the spherical cavity 18 in order to locate the disk 40 below the center of the cavity 18. The disk and partition 50 provide a fluid tight seal dividing the engine section 14 into two distinct chambers 54, 56. Because of the radial nature of the seal between the partition 50 and disk 40, the disk is free to pivot about an axis defined by the tip 52 of the partition 50.

Formed within the partition 50 is a conduit 58 which provides a passage for a heated fluid supplied from an external source (not shown). Heated fluid continually flows through the conduit 58 for the purpose of heating another fluid contained within the chambers 54, 56. Because of the location of the heating conduit 58 in the engine section 14, the chambers 54, 56 located in the engine section 14 are referred to as the hot chambers of the engine while the section 59 below the disk 40 in the engine section 16 is referred to as the cold section of the engine. While not shown in the drawings the engine section 16 may be in heat exchange relationship with a coolant to provide an even greater temperature differential between the hot chambers 54, 56 and the cold section 59 of the engine.

A conduit 60 interconnects one of the hot chambers, namely chamber 54, with the cold section 59 and a second conduit 62 connects the other hot chamber 56 with the cold section 59. The conduits 60, 62 open into the cold section 59 at diametrically opposed positions and are offset 90° from the axis of the convex portion 42 of the disk 40 (see FIGS. 5 and 6). As can be seen in FIG. 4, when the wedge 30 is in the position illustrated it divides the cold section 59 into two chambers, one of which is vacant and one of which is occupied by the wedge 30.

To better illustrate and explain the operation of the heat engine 10 reference is made to FIGS. 7-12 and FIG. 13 which shows the surface of the disk facing the hot chambers 54, 56. Assume operation of the engine 10 commences with the disk 40 in a horizontal position and the wedge 30 under the first and second quadrants of the disk 40 (FIGS. 7 and 10 and FIG. 13). Because the disk pivots about an axis formed at the apex 52 of the partition 50 the hot section 54 always is located over the first and fourth quadrants of the disk 40 while

hot section 56 always is located over the second and third quadrants of the disk. The fluid in one of the hot chambers, for example chamber 54, expands due to the fact that it is being heated by the hot fluid in the conduit 58. The expanding hot fluid in hot chamber 54 exerts a downward force on the first and fourth quadrants of the disk and an upward force on the underside of the disk 40 at the first and second quadrants by virtue of the hot gas being ducted to the cold chamber via conduit 60. The net resulting force tends to rotate the disk 40 in a counterclockwise direction as viewed in FIG. 7.

Because the spherical wedge 30 is sealingly engaged to the disk 40 by means of a rotary joint 38 and 42 that allows the spherical wedge 30 to pivot on an axis that is perpendicular to the axis of the disk 40, and transmits rotary motion of the disk 40 to member 30 that is connected to the crank member 24 through a rotary joint 28, FIG. 15. The oscillations of disk 40 and spherical wedge 30 causes shaft 22 to rotate about axis 64. This combination of forces and motion results in the disk 40 pivoting counterclockwise as viewed in FIG. 7 so that the first and fourth quadrants move downwardly. Furthermore, the wedge rotates so that the end of the wedge which is under quadrant one moves downwardly in order to remain in sealing engagement with the disk 40 at the same time that it rotates in a direction to transfer it from being under quadrants one and two toward being under quadrants three and four.

As the disk pivots so that the first and fourth quadrants move downwardly, the volume of hot chamber 54 increases and the volume of hot chamber 56 decreases. The motion of the disk 40 and wedge 30 is such that with movement of the disk from a horizontal position (FIGS. 7 and 10) to an angular position (FIGS. 8 and 11) and back to a horizontal position (FIGS. 9 and 12) the wedge 30 completes a 180° rotation, moving from under quadrants one and two to under quadrants three and four. This also provides a 180° rotation of the shaft 22 which is attached to the wedge 30. Continuing the movement of the system, the gas in hot chamber 56 expands and the disk 40 now pivots so that the quadrants two and three move downwardly increasing the volume of hot chamber 56 and effecting movement of the wedge 30 from being under quadrants three and four to returning to residing under quadrants one and two thereby completing a 360° rotation of the wedge 30 and shaft 22.

This movement of the disk and wedge also produces a variance in pressure and volume within the several chambers in the spherical cavity 18, which volume variance follows the P-V diagram of FIG. 1. In other words, the hot chamber 54 and cold section connected therewith through conduit 60 undergoes an expansion of volume at constant temperature T_1 , a reduction in pressure as the temperature of the gas drops from T_1 to T_2 , a reduction in volume at constant temperature T_2 and then an increase in pressure as the temperature of the gas increases from T_2 to T_1 . In this manner the hot section 54 and its associated cold section follow the Stirling cycle. Similarly hot section 56 and its associated cold section also follow the Stirling cycle.

Because the diameter of the disk 40 is less than the inside diameter of the spherical cavity 18, the disk 40 resides at a position slightly below a diametral plane. This permits the disk to seal against the walls of the spherical cavity when the system is cold and during its

warm up time. As the disk gets hotter it expands and rides up toward the diametral plane of the spherical cavity 18, thereby maintaining its sealing relationship with the walls defining the cavity. In order to accommodate this upward movement of the disk, a resilient tip, such as a spring loaded nose 66 is provided at the tip 52 of the partition 50. The material for the disk and size of the disk are chosen so that when the disk is at its maximum temperature its diameter will be no greater than the inside diameter of the spherical cavity 18 and will properly seal therewith.

In a second embodiment of this system as shown in FIGS. 14 and 15 the construction is basically the same as was described above with reference to the engine illustrated in FIGS. 3 and 4. As above, a wall 70 having a conduit 72 formed therethrough divides the upper chamber into two hot sections 74, 76. A pair of generally triangularly shaped insulator members 78, 80, each of which has a concavity 82, 84 to accommodate the conduit 72 formed in the wall 70, rest upon or are attached to the disk 40 and pivot within their respective hot sections 74, 76 as the disk pivots upwardly and downwardly. The insulator members serve to insulate the cold section 86 from the hot chambers 74, 76. The operation of the heat engine of this second embodiment is the same as that described above with reference to the first embodiment.

In order to increase the efficiency of the heat engine of this invention it is also contemplated that regenerative means can be used. The hot gas from the hot chamber 54, 56 (74, 76—the second embodiment) flow through the conduits 60, 62 toward the cold section 59 and pass through the regenerators 90, 92 giving up most of their heat to the plates and material in the regenerator. Upon returning from the cold section 59 to the hot chambers 54, 56, the gases pick up the stored heat from the regenerator, thereby saving on fuel for heat input.

What is new and desired to be secured by Letters Patent of the United States is:

1. A rotary engine comprising:

- a. an engine body having a cavity therein shaped to form the major portion of a sphere,
- b. a disk mounted within said cavity for pivotal movement about an axis, said disk dividing said cavity into a first and a second section, each section being adapted to contain a fluid therewithin,
- c. means for heating the fluid in said first section,
- d. conduit means providing fluid flow connection between said first and second sections,
- e. a first member adapted to move about a first axis,

- f. a second member mounted within said second section for eccentric movement about said first axis, said second member being drivingly connected to said first member,

- g. second member pivot means on said disk aligned at a preselected angle with respect to the pivot axis of said disk, said second member sealingly engaging said pivot means, said disk and second member defining a chamber in said second section, pivoting movement of said disk and eccentric movement of said second member varying the effective volume of said chamber in said second

section and pivoting movement of said disk varying the volume of said first section.

2. A rotary engine as defined in claim 1 wherein said second member pivot means is orthogonal to the pivot axis of said disk.

3. A rotary engine as defined in claim 1 wherein the periphery of said disk is in sealing engagement with the surface of said body which defines said cavity.

4. A rotary engine as defined in claim 3 wherein the diameter of said disk when cold is less than the diameter of said cavity and wherein the diameter of said disk at operating temperature is no greater than the diameter of said cavity.

5. A rotary engine as defined in claim 1 including a regenerator and wherein said conduit means provides fluid flow connection between said first section and said regenerator and between said regenerator and said second section.

6. A rotary engine as defined in claim 1 including a partition dividing said first section into first and second fluid containing chambers, first conduit means providing fluid flow connection between said first chamber and said second section, second conduit means providing fluid flow connection between said second chamber and said second section.

7. A rotary engine as defined in claim 6 wherein said partition sealingly engages said disk along a diametral line thereof defining the pivot axis of said disk and wherein said second member pivot means is orthogonal to said diametral line.

8. A rotary engine as defined in claim 6 wherein said second member is a wedge having one surface shaped to sealingly mate with and slide upon the wall of said cavity, said wedge having an apex which sealingly engages said second member pivot means.

9. A rotary engine as defined in claim 6 wherein said means for heating the fluid in said first section includes means for heating the fluid in said first and second chambers.

10. A rotary engine as defined in claim 8 wherein said engine body includes a cylindrical aperture therethrough communicating with said second section, said cylindrical aperture having an axis orthogonal to the pivot axis of said disk, said first member being a shaft extending through said cylindrical aperture, said shaft being drivingly connected to said wedge whereby eccentric movement of said wedge effects rotary movement of said shaft.

11. A rotary engine as defined in claim 10 including a third member fixedly attached to said shaft and offset with respect to the axis of said shaft, said wedge mounted on said third member for rotational movement relative thereto.

12. A rotary engine as defined in claim 6 including a regenerative means and wherein said first and second conduits direct the flow of fluid from said first and second chambers respectively to said regenerative means to said second section.

13. A rotary engine as defined in claim 6 including a first insulator member drivingly associated with the portion of said disk in said first chamber and a second insulator member drivingly associated with the portion of said disk in said second chamber.

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