United States Patent [19]

Berry

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[45] **June 11, 1974**

[54] **SPHERICAL DISPLACEMENT DEVICE AND SEAL MEANS THEREFOR**

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[73] Assignee: **Commercial Metals Company,** Dallas, Tex.

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[21] Appl. No.: **318,259**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 110,928, Jan. 29, 1971, abandoned.

[52] **U.S. Cl.** **418/68,** 418/112, 418/143, 277/160

[51] **Int. Cl.** **F01c 3/00,** F01c 19/00, F04c 27/00

[58] **Field of Search** 418/68, 104, 112, 116, 418/142, 143; 277/160, 161

[56] **References Cited**

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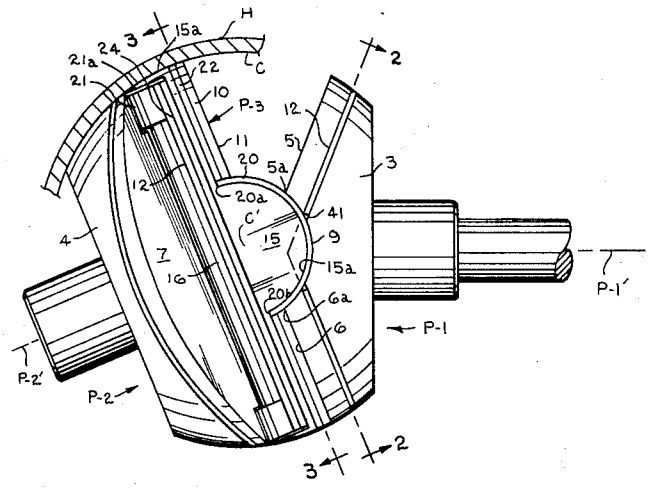
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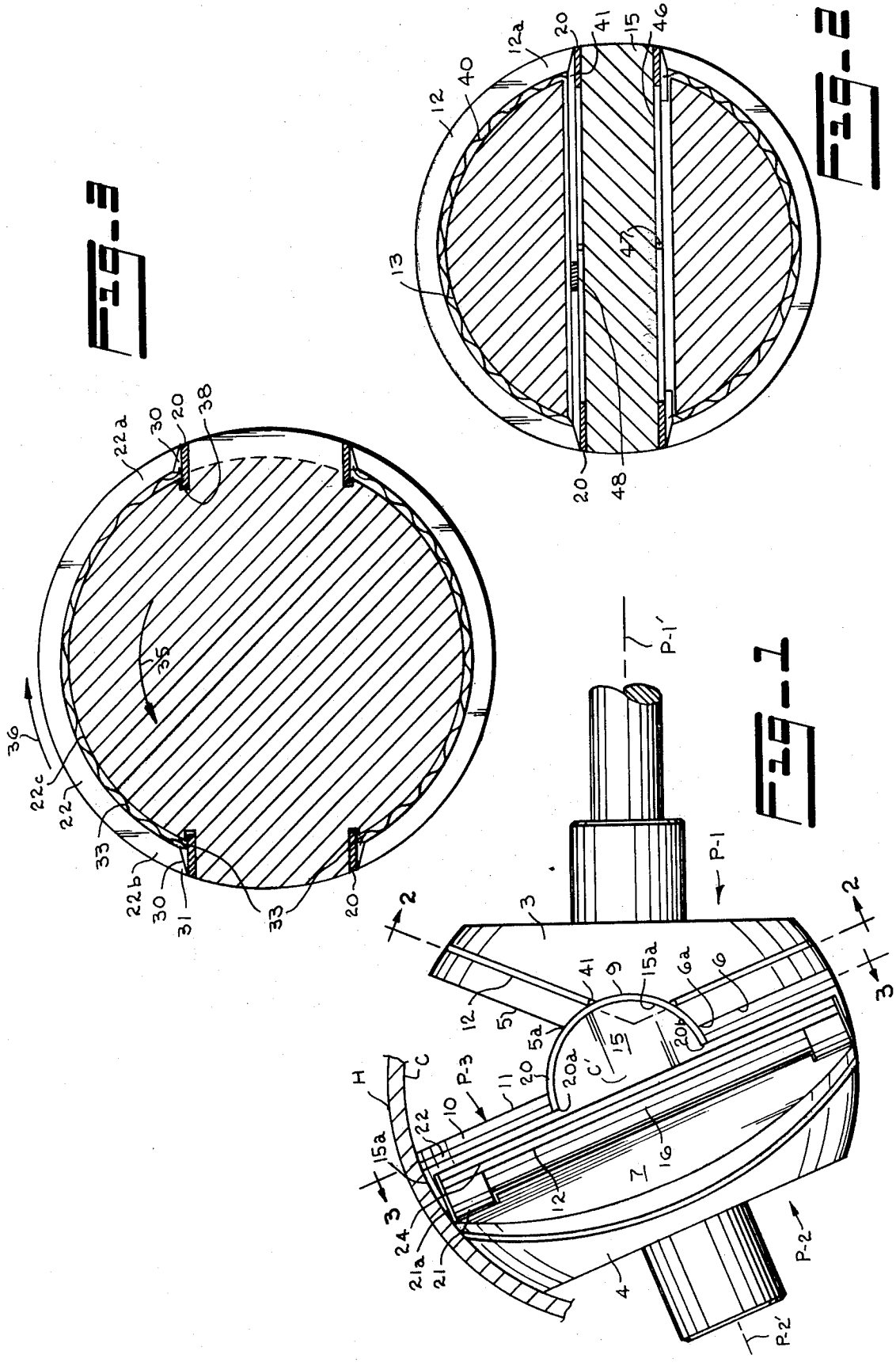
Primary Examiner—Carlton R. Croyle
Assistant Examiner—John J. Vrablik
Attorney, Agent, or Firm—Pravel, Wilson & Matthews

[57] **ABSTRACT**

The present invention relates to a positive displacement spherical device comprising a housing having a generally spherical cavity of chamber therein with a diametrically extending piston positioned between a pair of rotating wedge-shaped pistons which have their axes disposed at an angle with respect to each other so that rotation of the wedge-shaped pistons causes the central diametrically disposed piston to simultaneously rotate and oscillate to thus positively displace fluids between the adjacent surfaces of the central piston and the end pistons. The present invention also includes seal means for sealing piston to piston and piston to housing in such spherical displacement device to prevent leakage from the high pressure to the low pressure chambers formed between the pistons in the housing. Such spherical displacement device can be used either as a pump, compressor or gas expander and, with the addition of suitable ignition apparatus, as an internal combustion engine.

12 Claims, 22 Drawing Figures




FIG-2
FIG-3
FIG-1
12a
20
41
15
46
40
12
13
47
48
22a
30
38
36
22c
22
22b
31
33
P-1'
P-1
P-2
P-2'
P-3
2
3
9
15a
6a
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5a
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C'
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16
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21a
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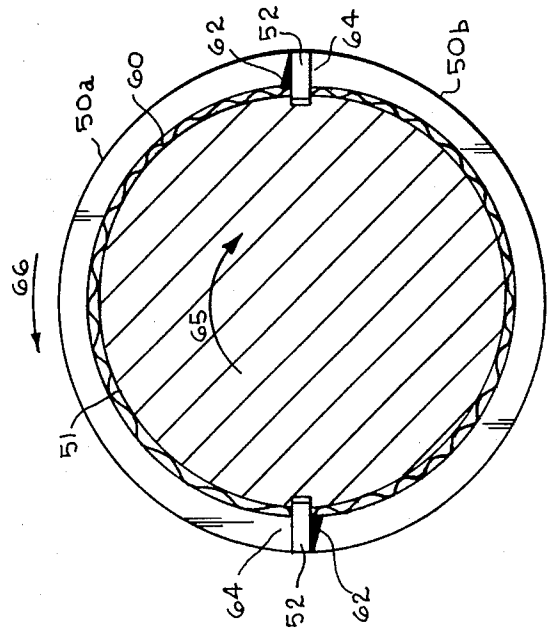


FIG-5

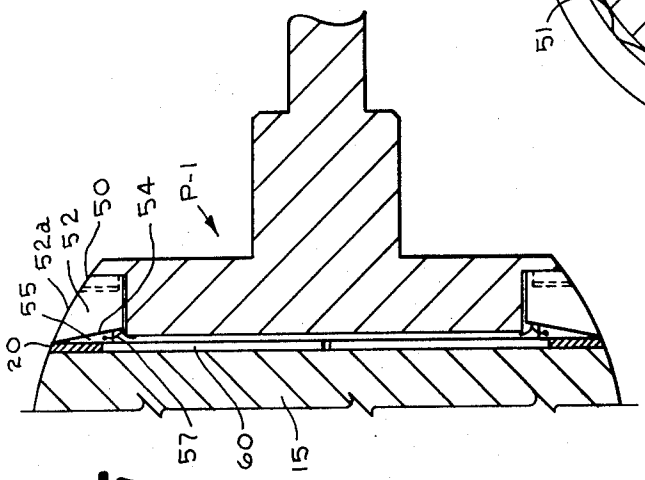


FIG-6

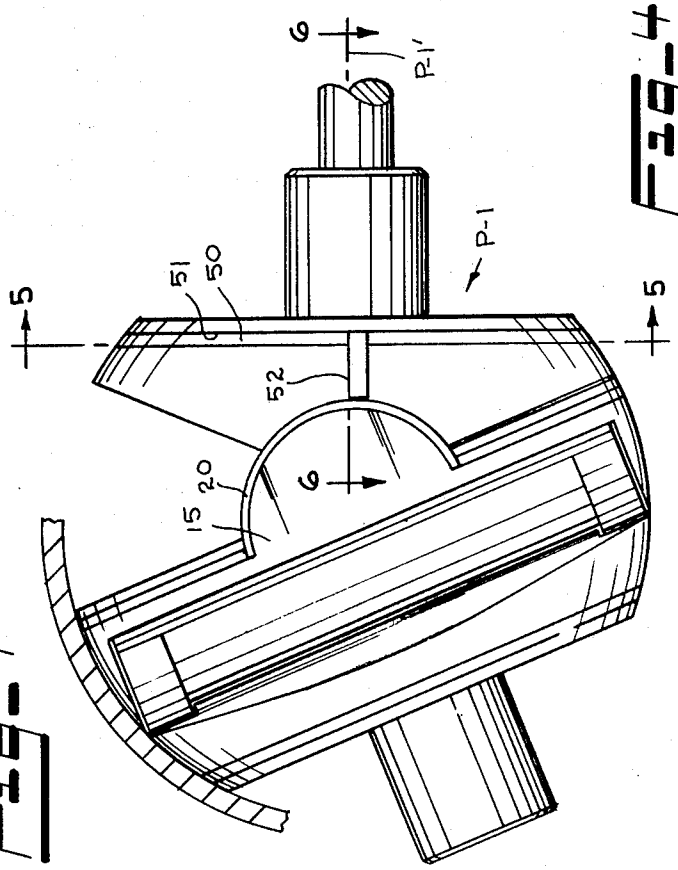


FIG-4

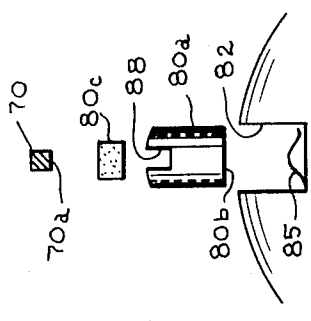


FIG-7

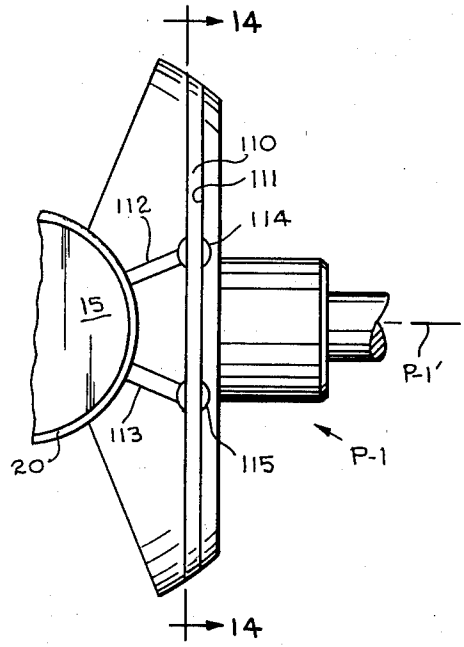


Fig-13

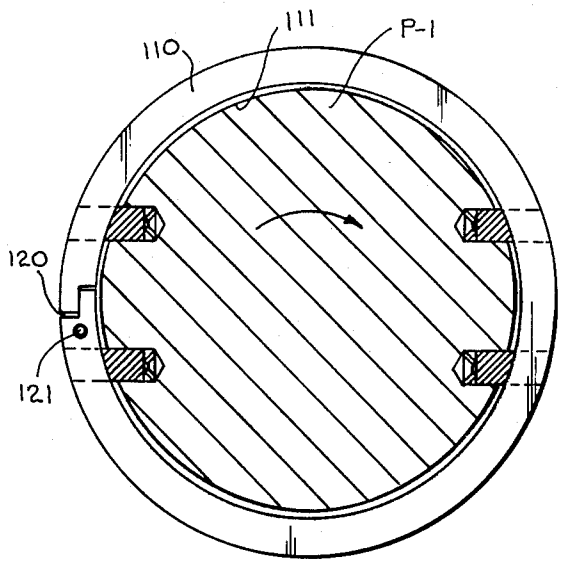


Fig-14

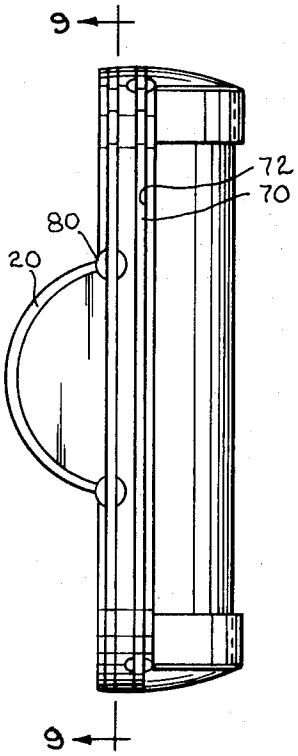


Fig-8

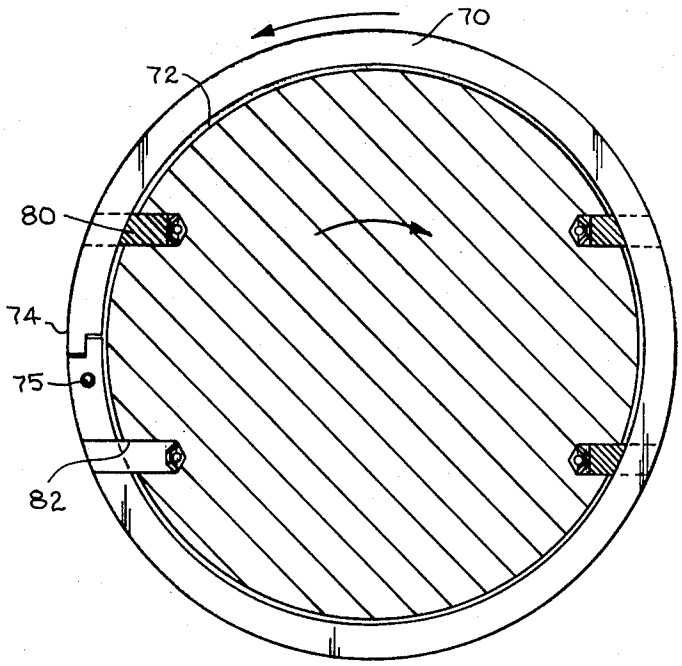
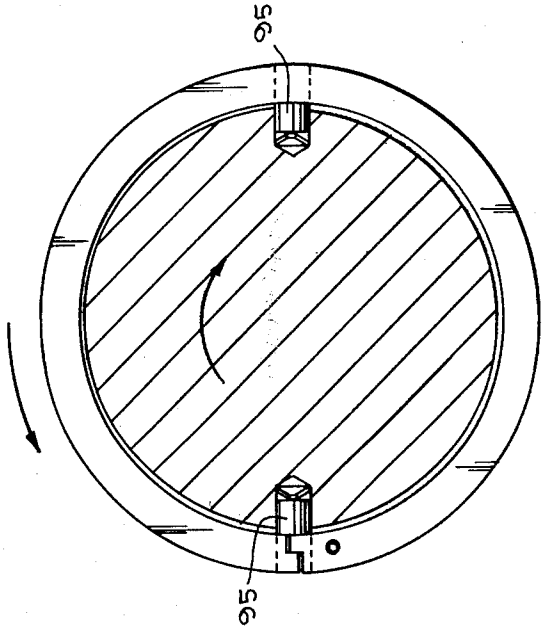


Fig-9

Fig-12



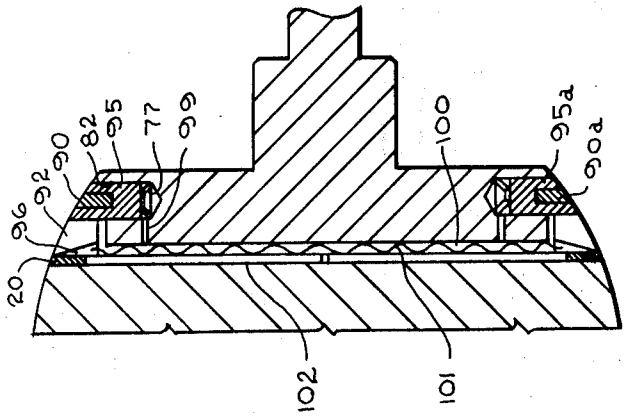


Fig-11

Fig-10

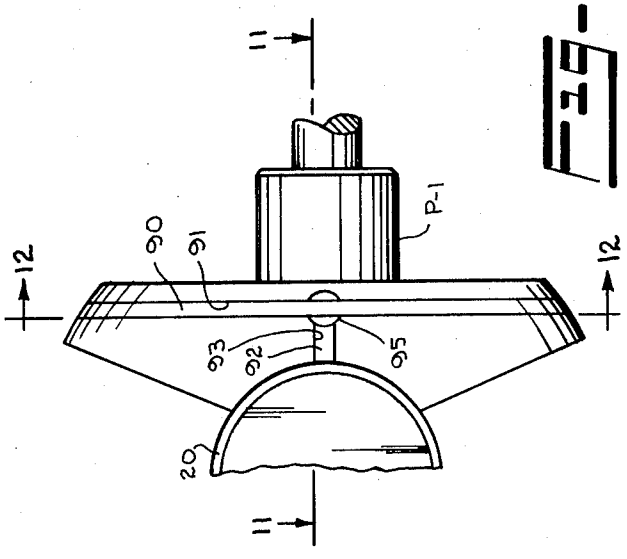
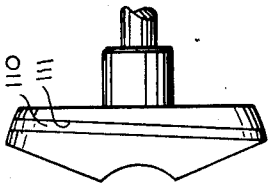


Fig-13A



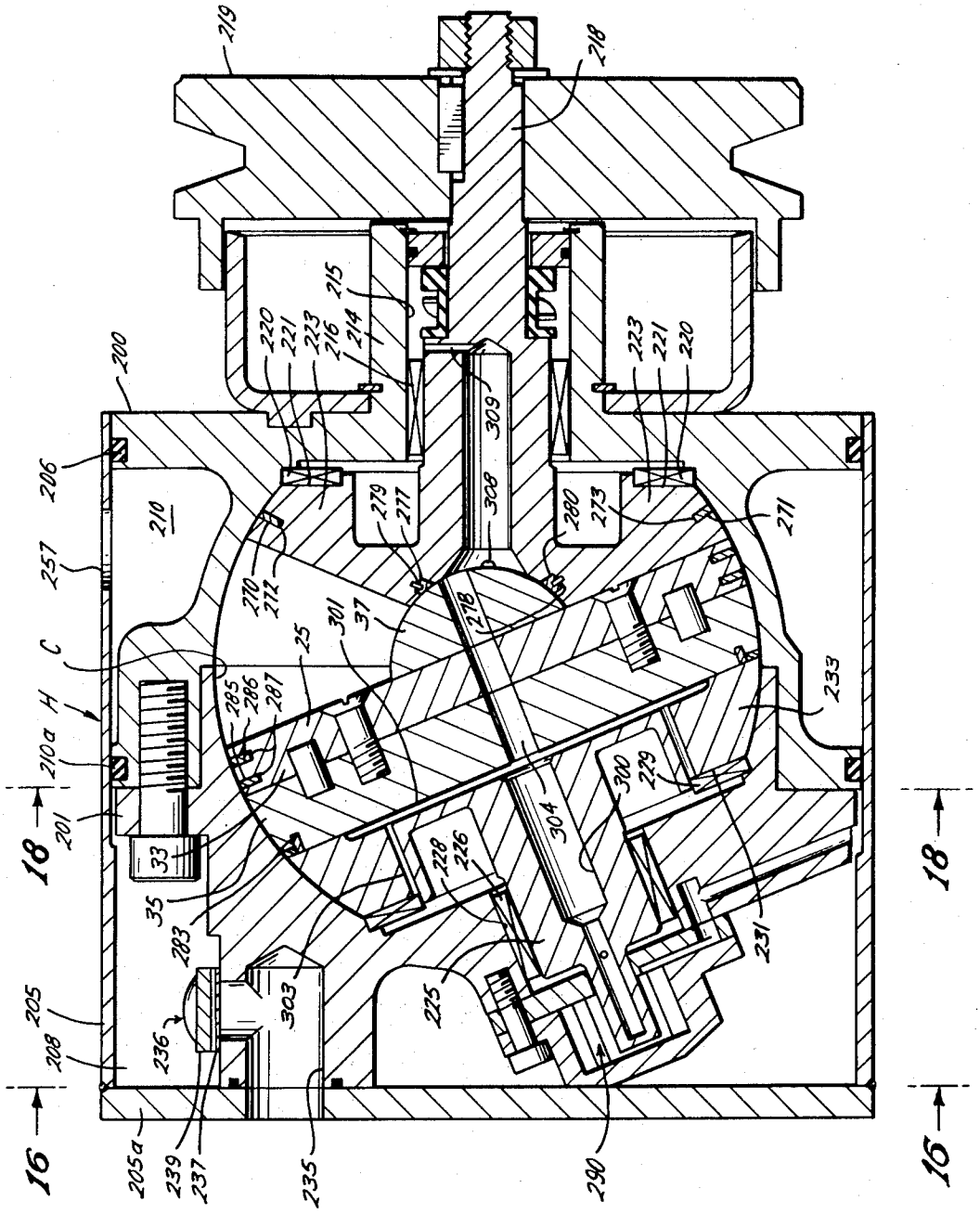

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Fig. 15

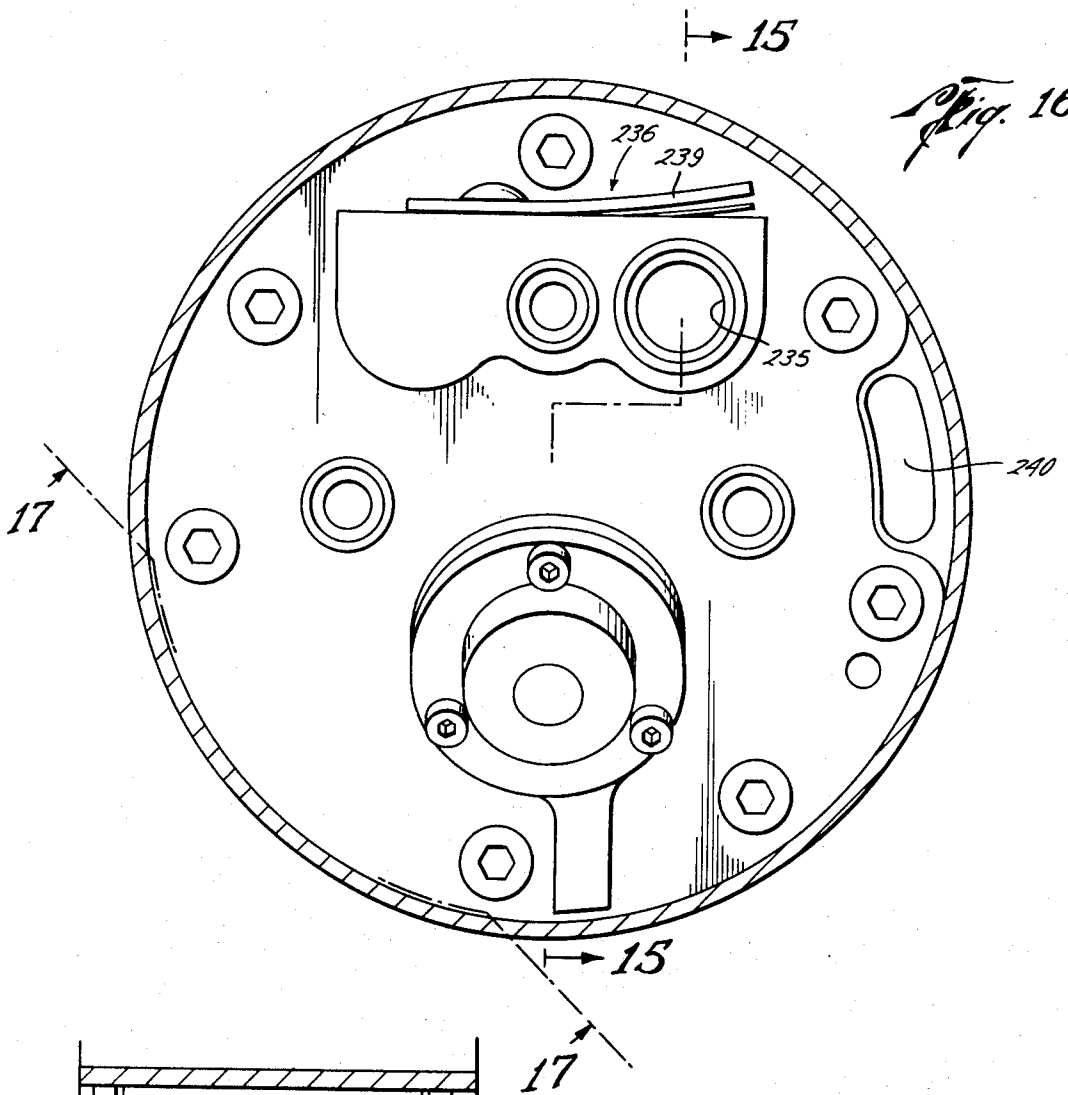


Fig. 16

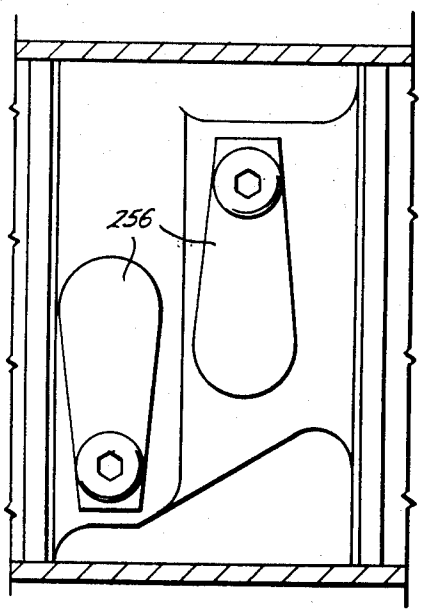


Fig. 17

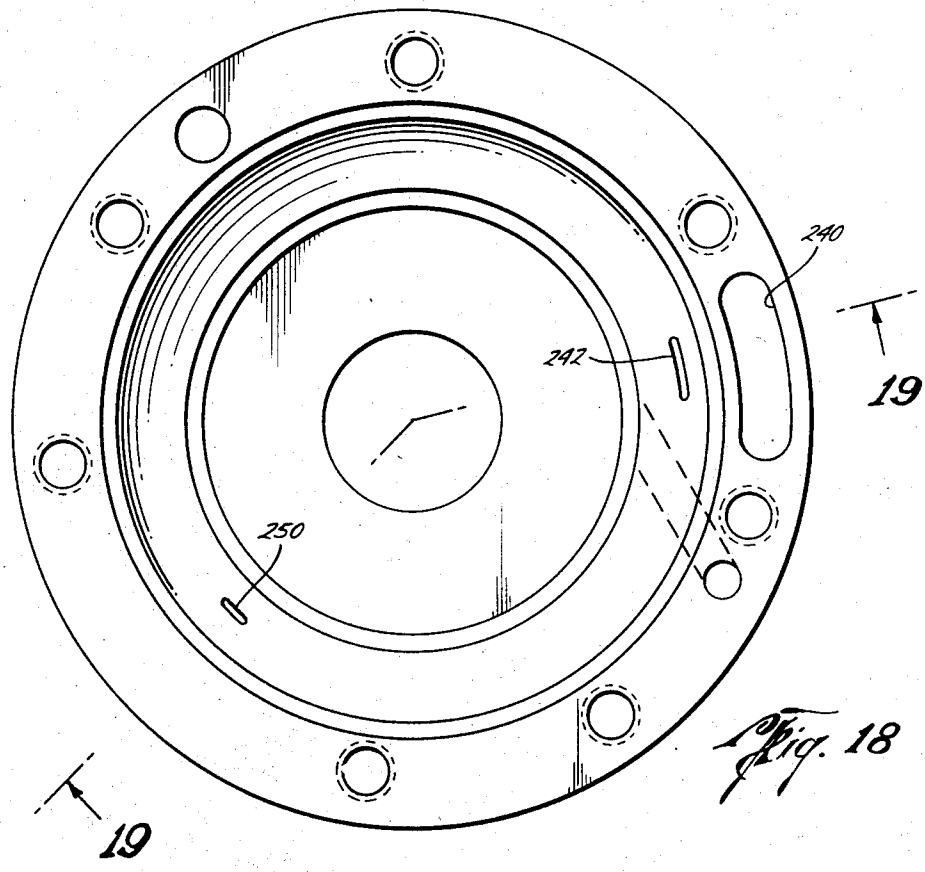


Fig. 18

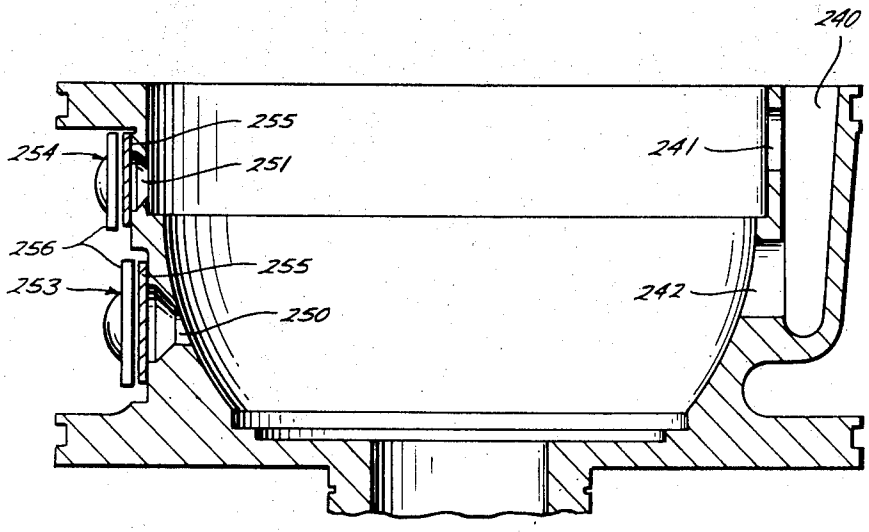


Fig. 19

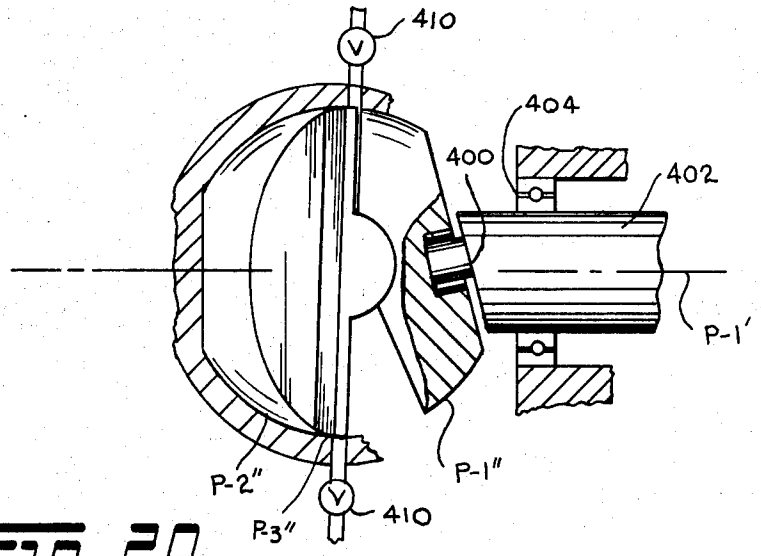


Fig-20

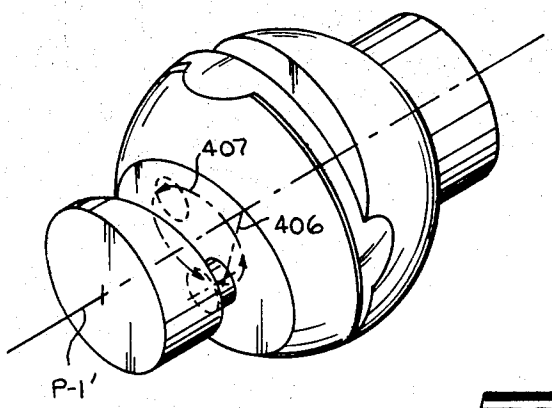


Fig-21

SPHERICAL DISPLACEMENT DEVICE AND SEAL MEANS THEREFOR

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of application Ser. No. 110,928, filed Jan. 29, 1971 and now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention pertains to a spherical displacement device and means for sealing between the moving parts thereof. The term "spherical displacement device" shall, for the purpose of this patent application, mean a device having a chamber therein which is at least partially spherical and having one or two wedge-shaped spherical sections or pistons with faces converging at the center of the spherical housing with a disc-shaped center piston extending diametrically of said spherical housing and adapted to rotate with said wedge-shaped end piston and to also oscillate with respect thereto. Suitable inlet and discharge passages are provided in the housing so as to draw in and discharge the volume displaced on each revolution of the pistons. In some embodiments, one of the wedge-shaped end pistons is fixed against rotation and the other is mounted on a rotatable crank which is inclined toward the center of the sphere but offset with respect to the axis of rotation of such crank so as to cause the crank to describe a cone as it rotates. With this configuration, the center piston is caused to oscillate between the fixed rear piston and the rotating first piston.

2. Description of the Prior Art

There have been various attempts in the past to provide spherical power devices which overcome the inherent inertial disadvantages of reciprocating devices. Such spherical displacement devices typically employ one or more wedge-shaped pistons which are mounted for rotation in a spherical housing on opposite sides of a central piston which rotates with and oscillates between the wedge-shaped end pistons to provide an improved pump, compressor or engine. In these prior art devices, which are typified by the U.S. Pat. to Froude, Nos. 295,380 and 312,116, as well as in the U.S. Pat. to Hurdle et al, No. 389,927, the end pistons are mounted for rotation about axes which converge at the center of the spherical housing. These old patents show the three-piston arrangement employed in spherical power devices and disclose various means for sealing the pistons with respect to each other and with respect to the surrounding spherical housing. However, each of these devices is burdened with the inherent shortcomings of the various sealing means employed for sealing between the respective pistons and between the pistons and surrounding housing. While some of the seals disclosed in these patents may be suitable for use at low pressures, they are unsuitable for use in high pressure devices, such as freon compressors, inasmuch as they allow the high pressure fluid to leak from behind the seals or along the seals and thus escape from the high pressure to the low pressure chamber and thereby render the devices inefficient or ineffective for use as high pressure compressors. Various other spherical power devices have been proposed, however, many of them do not even attempt to provide seal means for sealing between the various pistons and the surrounding spherical housing.

While the prior art patents have generally placed their sealing rings in obvious locations, such as around the central and outer pistons and across the central piston journals, they have failed to provide a leak-tight seal system which will seal all leak paths in each individual chamber. This in a result of not providing a seal system which adjusts to the variation of clearance between the internal rotating members and the inside spherical bore of the housing, i.e., variations in clearance due to imperfections in manufacturing and deflections of the rotating parts due to heat and loads. Further, the prior art sealing systems have not sealed effectively at all joints; that is, to be effective in high pressure systems, there must be provision for compensating for wear so as to maintain a positive seal at each seal joint regardless of which of the individual seals wears. Also, provision must be made to prevent high pressure working fluid from leaking along a path down the face of the seal and under its inside radius to the low pressure side.

SUMMARY OF THE INVENTION

The present invention comprises a sealing system for sealing all leak paths found in a spherical displacement device which comprises a housing having a generally spherical chamber therein with a central piston extending diametrically of the chamber and with semi-cylindrical journals extending diametrically across opposite sides or faces of the central piston and disposed at substantially right angles relative to each other. End pistons which are wedge-shaped spherical sections are disposed on opposite sides of the central piston at an angle other than 180° with respect to each other and have diametrically extending semi-cylindrical grooves therein for receiving the respective journals formed on the opposite sides of the central piston. The sealing system with the present invention includes a plurality of circumferentially extending ring seal segments which are provided on the spherical shaped portion of the end pistons for sealing between them and the spherical housing as well as circumferentially extending ring seal segments which are positioned on the outer edge of the central disc piston for sealing between it and the outer spherical housing. Further, pin end seals are provided on the ends of the journals which connect the center and end pistons. With this sealing arrangement, plug seals are also provided with the circumferentially extending ring seal segments to prevent high pressure leaks along or behind the ring seal segments. Further, wedge-shaped seal members are provided for sealing between the pin end seals on the journals and the side seals on the spherical section end pistons. With this arrangement, a sealing system is provided which employs only metal or other rigid parts for sealing to thus provide a means for sealing against the loss of relatively high pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partial side view showing the internal pistons of a spherical displacement device including two end pistons on opposite sides of a central disc-shaped piston arranged for rotation in the spherical chamber;

FIG. 2 is a sectional view taken on line 2—2 of FIG. 1 showing the seals on the end pistons;

FIG. 3 is a sectional view taken on line 3—3 of FIG. 1 showing further details of the seals on the disc-shaped central piston;

FIG. 4 is a partial side view of the spherical displacement device showing the details of an alternate piston seal arrangement;

FIG. 5 is a sectional view taken on line 5—5 of FIG. 4 showing the ring seal means on the end piston;

FIG. 6 is a sectional view taken on line 6—6 of FIG. 4 showing additional details of the seals on the end piston;

FIG. 7 is an exploded view of the plug seal;

FIG. 8 is a side view of the disc-shaped center piston with plug seals in association with the ring segment seals;

FIG. 9 is a sectional view taken on line 9—9 of FIG. 8 showing additional details of the plug seals;

FIG. 10 is a side view of an alternate embodiment of the seal ring on the end piston;

FIG. 11 is a sectional view taken on line 11—11 of FIG. 10;

FIG. 12 is a sectional view taken on line 12—12 of FIG. 10 showing additional details of the sealing arrangement for the end pistons;

FIG. 13 is a side view of another alternate embodiment of the sealing arrangement for an end piston;

FIG. 13A is a side view of an alternate embodiment of an end piston with the circumferentially extending ring disposed at an angle with respect to the axis of rotation of the piston;

FIG. 14 is a sectional view taken on line 14—14 of FIG. 13 showing other details of this alternate sealing arrangement;

FIG. 15 is a sectional view of the compressor embodiment of the spherical power device of the present invention including means for sealing the various pistons with respect to ths spherical housing;

FIG. 16 is a rear elevation taken on line 16—16 of FIG. 16 showing inlet ports in the compressor housing;

FIG. 17 is a sectional view taken on line 17—17 of FIG. 16 showing additional discharge valve details;

FIG. 18 is a partial sectional view taken on line 18—18 of FIG. 15 showing the inlet and discharge passages in the compressor housing;

FIG. 19 is a sectional view taken on line 19—19 of FIG. 18 showing additional details of the inlet and discharge passages in such housing.

FIG. 20 is a schematic view showing an alternate embodiment of the spherical displacement device wherein one end piston is fixed and the other is mounted for rotation so as to cause the center piston to oscillate between the fixed and rotatable end pistons.

FIG. 21 is an isometric view of the embodiment shown in FIG. 20.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in FIG. 1 of the drawings, the apparatus of the present invention comprises a housing H having a spherical chamber or cavity C formed therein for receiving the pair of end pistons P-1 and P-2 which are rotatably mounted in the housing H with the axis P-1′ of the piston P-1 aligned at an angle with respect to the axis P-2′ of the piston P-2 with such axes converging at the center C′ of the spherical chamber C. Between such facing pistons P-1 and P-2 is mounted the central or intermediate piston P-3 which rotates with the end pistons and simultaneously oscillates between such pistons as it rotates with them.

The piston P-1 comprises a substantially hemispherical body 3 having a pair of inwardly inclined faces or surfaces 5 and 6 which are connected by their inner edges 5*a* and 6*a* by longitudinally extending concave groove or channel 9 that extends diametrically across the piston P-1. As shown, the piston shaft 14 on which the piston is rotatably mounted in the housing H, is positioned on the axis P-1′ which extends at essentially a right angle to the groove 9. The piston P-2, also shown in FIG. 1 of the drawings, is substantially identical to the piston P-1 in that it also has a substantially hemispherical body 4 and is provided with inclined faces 7, only one of which is shown in FIG. 1. Such piston P-2 is provided with a diametrically extending groove which is substantially perpendicular to the axis P-2′ on which the piston P-2 rotates.

The central or center piston P-3 comprises a circular plate or disc-shaped member 10 which also includes substantially plane and parallel opposite sides 11 and 12, respectively. Each side is divided into sections by means of the diametrically extending journal means 15 and 16 which extend across the surface of the plane sides 10 and 11. Such journals 15 and 16 are provided with a convex curved semi-cylindrical outer surface which is substantially the same radius as the groove 9 in the piston P-1 in which such journal 15 is normally received. Such journals 15 and 16 are disposed at substantially right angles with respect to each other and are on opposite sides of the disc-shaped member 10. Also, the outer circumferentially extending edge of the disc-shaped member 10 is curved at substantially the same radius as the inner surface of the spherical chamber or cavity C in the housing H.

The seals shown in FIG. 1 of the drawings include the pin end seal members 20 and 21, respectively, which are generally semi-cylindrical so as to conform to the outer surface of the journal members 15 and 16. The center piston is also provided with center ring seals 22 and 24 which extend circumferentially around the outer perimeter of the center disc-shaped piston. Such rings 22 and 24 are disposed in suitable grooves in the curved edge of the center piston and are positioned with their ends abutting the pin end seals 20 and 21, respectively.

FIG. 3 shows additional details of the sealing arrangement for the center piston P-3 including the wedge-shaped end seal members 30 which engage the tapered ends 31 of the ring segment seals 22 and 24. Also shown is the spring member 33 which is positioned in the ring groove in the center piston for urging such ring segment seals 22 and 24 radially outwardly into engagement with the inner surface of the spherical chamber C. As shown in FIG. 3 of the drawings, when the piston P-3 is rotated in a counterclockwise direction as indicated by the arrow 35, the frictional force on the outer ring segment seals 22 urges such ring segment in a clockwise direction as indicated by the arrow 36. The frictional force on such ring segments tends to cause the ring 22 to resist rotation with the piston P-3 so that the trailing end 22*a* of the ring 22 is jammed against the wedge-shaped seals 30 and the adjacent pin end seals 20 in the side following rotation. This reaction along with the extending of the seals creates a clearance in the seal joint adjacent the ends 22*b* leading rotation

which would provide a leak path unless compensated for by the wedge-shaped seals **30** adjacent the leading ends **22***a* of the rings **22.** As shown in the drawings, such wedge-shaped seals are urged outwardly into sealing engagement between the tapered ends of the rings **22** in the adjacent surface of the pin end seal **20** by means of the ends of the springs **33.**

The pin end seals **20** and **21,** provided at the opposite ends of the diametrically extending journals **15** and **16** on the center piston, are positioned in grooves **38** which extend further into the center piston body than the grooves such as **22***c* in which the outer seal rings **22** and **24** are positioned in order to prevent high pressure fluid from leaking under such outer rings, around the ring groove and under the opposite ring on the low pressure side. In other words, the pin end seals close the ends of the ring grooves such as **22***c* to prevent high pressure fluid from leaking from one groove to another. Also, to prevent fluid from passing between the pin end seals **20** and **21** and the adjacent journal surface **15***a* as shown in FIG. **1,** the radius of the journal **15** and the radius of the adjacent side of the pin end seal **20** are substantially the same. To provide a satisfactory seal, the pin end seal **20** must also seal at its opposite ends **20***a* and **20***b*. In order to accomplish this without making the parts extremely precise and expensive to manufacture, the pin end seal **20** is manufactured with a smaller arc length than the corresponding arc length of the journal **15** so as to permit the pin end seal **20** to slide around the journal some slight amount as a result of friction of the outer pistons as the center piston moves relative to the outer piston on the compression stroke. This friction causes one end of the pin end seal **20***a* or **20***b*, whichever is applicable, to contact the adjacent center piston face which in turn prevents the high pressure fluid under the outer center ring from leaking to the outside between the pin end seal and the center piston at either end of such pin end seal. Also, it should be noted that the outer edges such as **21***a* of the pin end seals are beveled or curved at their outer edge so as to conform to the spherical configuration of the ends **15***a* of the journal **15** and to fit the radius of the spherical chamber C.

Considering next the seals on the outer piston P-**1** as shown in FIGS. **1** and **2** of the drawings, the outer seal rings **12** which are positioned in ring grooves **13** in the piston P-**1** are forced outwardly against the inner spherical surface of the surrounding housing H by means of springs **40** as well as the fluid pressure which will leak under such outer piston seal rings. The seals **12** are free to adjust to variations in clearance between the spherical housing and the spherical rotor due to deflection, load or heat. The ends of the outer piston rings **12** are tapered at **12***a* so as to receive the seal wedges **41** which are carried in grooves aligned with the grooves of the outer ring seal **12** and which are provided with suitable springs **48** for urging the wedge-shaped seals outwardly into engagement with the tapered ends of the seals **12.** Such seal wedges or locks are free to move longitudinally of the journals, such as **15,** so as to fill the gap at the ends of the ring seals **12.** Thus, when the frictional forces imposed upon the seal **12** cause it to move relative to the piston P-**1,** the wedge-shaped member will tend to fill the gap and thereby prevent a leak path at the end of such ring seal. Also, the seals **41** overlap the pin end seal **20** so as to seal between the ends of the ring seal **12** and the adjacent pin end seal. Suitable spring means such as that illustrated at **48** may be used to urge the wedge-shaped seal members **41** longitudinally of the journal and into sealing engagement with the ends of the arcuate ring seal segments **12.**

Cross seals **46** are also provided for sealing between the journal **15** and the corresponding curved portion of the end piston P-**1** adjacent thereto. Such cross seals **46** seal the base of the pin end seals **20** and **21,** and as shown in the drawings, the cross seals are preferably provided with a lap joint **47** to permit longitudinal movement of the seals relative to the journal to compensate for pin end seal wear. Such lap joint normally comprises overlapping end segments of the seal members which are approximately one-half of the normal thickness of the cross seal. Such overlapping construction is provided to accommodate longitudinal movement between the various seal strips or pieces in the cross seal.

It will be appreciated that the outer piston seals referred to hereinabove must combine with the center piston seals to make a total system in which each chamber is sealed from the other chambers in the spherical displacement device.

As shown in FIG. **1,** the seals **12** are disposed in grooves **13** which are aligned substantially parallel to the planes of the faces **5** and **6,** respectively, of the piston P-**1.** An alternate embodiment of the sealing system of the present invention is shown in FIGS. **4, 5** and **6** of the drawings wherein the center piston seals are identical to those previously described with respect to the FIG. **1** embodiment but the seals for sealing the outer piston P-**1** are arranged to provide a circumferentially extending seal that is disposed in a plane substantially perpendicular to the axis of rotation P-**1**′ of the piston P-**1.** As shown in FIG. **4** of the drawings, the seal **50** is disposed in a groove **51** that is perpendicular to the axis of rotation of the piston P-**1** with a side seal **52** disposed in a plane substantially perpendicular to the plane of the seal **50.** The side seal **52** provides a means for sealing the ends of the ring segments **50** and also provides a means for sealing between the piston P-**1** and the pin end seal **20** on the journal **15.**

As shown in FIG. **6** of the drawings, the cross seals **52** cover the ends of the ring seal segments **50** and the groove **51** in which such ring seal segments are disposed. Such cross seals **52** are provided with a curved outer surface **52***a* which is shaped to conform to the inner surface of the spherical chamber and are provided with a tapered end portion **54** which is tapered or inclined to receive the wedge members **55** which are provided between the side seals **52** and the adjacent pin end seal **20.** As shown in FIG. **6** of the drawings, the wedge members **55** are provided with spring means **57** which urge the wedge outwardly so as to fill the space between the tapered surface of the side seal **52** and the adjacent surface of the pin end seal **20.** Also, as shown in FIG. **6** of the drawings, an inner cross seal **60** is shown for sealing between the center piston journal member **15** and the piston P-**1.** Also, as shown in the drawings, the wedge-shaped seals **55** overlap the juncture between the end of the cross seal **60** and the inner end of the pin end seal **20.**

FIG. **5** shows the circumferentially extending seal **50** which comprises segments **50***a* and **50***b* which are disposed in the groove **51** in the piston P-**1.** Spring means **60** are provided in the groove **51** beneath the segments **50***a* and **50***b* for urging them radially outwardly into en-

gagement with the inner surface of the surrounding spherical housing. The side seals **52** are shown on opposite sides of the piston P-1 with suitable wedge seal members **62** provided adjacent the tapered ends of the ring segments **50***a* and **50***b*, respectively, and positioned between such tapered ends and the adjacent side of the side seals **52**.

Also as shown in FIG. **5** of the drawings, the opposite end of the ring segments from the tapered end is provided with a radially extending surface **64** for engaging the adjacent side of the side seal **52**. The outer ring seal segments **50***a* and **50***b* are free to float and compensate for wear or misalignment between the inner pistons and the outer spherical housing. As shown, rotation of the end piston P-1 clockwise as indicated by the arrow **65** will create frictional forces in a counterclockwise direction as indicated by the arrow **66** which will tend to move the ring seal segments **50***a* and **50***b* in a counterclockwise direction thereby forcing the ends **64** of the ring seal segments into sealing engagement with the adjacent side seal **52** and also opening or spreading apart the opposite tapered ends of the ring seal segments from the opposite sides of such side seals **52**. The wedge-shaped seal members **62** adjacent the tapered ends will move radially outwardly to close any gap between such tapered ends of the seal segments **50***a* or **50***b* and the sides of the side seal **52** adjacent thereto. Further, it will be appreciated that in the FIG. **4** embodiment the side seal members **52** engaging the ends **64** drive such segments with the piston P-1 and cause them to rotate with the pistons. Such side seals also prevent high pressure fluid from leaking from under the outer ring seals from the high pressure side to the low pressure chamber be being recessed deeper into the piston than the outer seal ring groove **51** as best seen in FIG. **5** of the drawings. It will also be appreciated that the seal **50** may be formed of a single piece rather than of a plurality of segments in which case, one of the side seals **52** will be relieved or notched so as to enable the one-piece seal to pass therethrough. Such single piece seal will have one end such as the end **64** which engages one side of a side seal and another end tapered as illustrated in FIG. **5** of the drawings with a suitable wedge-shaped seal disposed between the tapered end and the adjacent side of the side seal member.

FIGS. **7, 8** and **9** show details of another preferred embodiment of the apparatus of the present invention which includes a plurality of plug seals used in conjunction with the various ring seal segments for sealing the spherical displacement device. As shown in the drawings, circular rings or ring seal segments **70** extend around a circumference of the central piston P-3 in suitable grooves **72** formed in the outer edge thereof. As shown a lap joint **74** is provided at the ends of the ring **70** to facilitate placing the ring on the central piston and helps prevent high pressure gas from leaking from under ring and when made as shown the edge trailing rotation holds down the leading edge of the ring and prevents it from hanging ports or other openings in the housing surface. A pin **75** is provided for locking the ring in the groove to thereby prevent from rotating relative to the piston.

Plug seals **80** are provided for sealing each ring seal **70** at its juncture with the opposite ends of the pin end seal **20**. The plug seals **80**, which are shown in an exploded view in FIG. **7**, are disposed in suitable cylindrical openings **82** formed in the center piston or the end pistons, at the case may be. Such plug seals comprise a tubular body **80** having an opening **80***b* extending therethrough and having a notch **88** in the outer end for receiving the ring seal **70**. Such plugs are additionally provided with a slip fit in the openings **82** and are preferably provided with springs **85** for urging the plugs outwardly into engagement with the surrounding seal ring **70**. As shown in the FIG. **7** embodiment, the plug seals **80** comprise a tubular member having a passage or opening **80***b* extending therethrough for receiving a sliding piston **80***c* which is urged outwardly by means of fluid pressure which is introduced into the cylindrical opening **82** in a manner which will be described in detail hereinafter. The piston **80***c* is designed to have a sliding fit in the passage **80***b* so that it can be urged outwardly so as to engage the inner surface **70***a* of the ring **70**. The outer end of the plug **80***c* is curved to conform to the inner surface or radius of the seal ring **70** and the outer end of the tube **80***a* is curved so as to conform to the radius of the spherical chamber in which the center piston rotates. The depth of the notch **88** inwardly of the tubular member **80** need not be held to close tolerance since the sliding piston **80***c* will move outwardly into engagement with the inner surface of the ring **70** to form a seal therewith and thus compensate for any difference between the depth of the notch and the thickness of the seal ring **70**. Thus, by using two pieces (the tubular member **80***a* and the piston **80***c*) the number of critical dimensions which must be held in manufacturing is reduced. However, it will be appreciated that a solid plug may be provided with a notched end for sealing the outer seal ring in the central piston.

FIG. **10** shows an alternate embodiment of the seal system of the present invention wherein a circumferentially extending ring seal **90** is provided in a suitable groove **91** formed on the piston P-1 with the seal **91** aligned substantially perpendicular to the axis of rotation P-1′ of the piston P-1. The side seal **92** is disposed substantially perpendicular to the circumferentially extending seal **90** and is disposed in the suitable groove **93** in the body of the piston P-1. A plug seal **95** is provided at the juncture of the side seal **92** and the ring seal **90** as shown in FIGS. **10** and **11** of the drawings. Such side seal **92** is substantially the same as the side seal **52** shown in FIG. **6**. Such side seal **92** has a tapered forward edge which is inclined to receive the wedge-shaped seal member **96** which is similar to the wedge-shaped seal **55** shown in FIG. **6**. The plug seal **95** is slidably mounted in the cylindrical opening **82** formed in the piston P-1. The seal **82** has a notch at its upper end for receiving the seal ring **90** and a spring **97** is provided in the lower end of the cylindrical opening for urging the plug **95** outwardly. Also, as shown in FIG. **11** of the drawings, a passage **99** communicated fluid pressure produced by operation of the spherical power device to the chamber or opening **82** for urging the plug **95** radially outwardly into sealing engagement with the seal ring **90**. The passage **99** is connected to the groove **100** in which the spring **101** and cross seal **102** are normally positioned. Thus, in the event high pressure fluid leaks behind the cross seal member it will be communicated to the cylindrical opening **82** behind the plug seal **95** and such high pressure fluid will then be used to urge the plug outwardly and assist in sealing the piston P-1 with respect to the surrounding spherical housing.

Also, as shown in FIG. 11 of the drawings, the outer end of the plug seals **95** are provided with a curved surface **95***a* which corresponds to the radius of the spherical chamber in the housing H. Further, the seal ring **90** is also provided with a curved surface **90***a* that also conforms to the radius of such spherical chamber.

FIG. 12 is similar to FIG. 9 in that it shows the plug seal **95** in conjunction with the ring seal **90,** however, the FIG. 12 embodiment has only a pair of plug seals **95** as there is only a single plug seal on each side of the end piston P-**1.**

As shown in FIG. **13**A of the drawings, there is another alternate embodiment of the seal means of the present invention which includes a circumferentially extending seal member **110** which is disposed in a groove **111,** wherein the groove **111** is inclined at an angle with respect to the axis P-1′ of the piston P-**1** so as to be a few degrees out of perpendicular with that axis. With this arrangement, it will be appreciated that the circumferentially extending seal **110** will be caused to wobble with respect to the axis of rotation P-1′ as the piston P-**1** is rotated so to thereby interject some lateral movement or sweep in the course of the rotating seal **110** with respect to the inner surface of the spherical housing. Such sweeping motion will facilitate the lubrication of the piston seal **110** as well as the area of the spherical housing which is swept by the wobbling rotation of the seal in the housing.

FIGS. **13** and **14** show another alternate view of a sealing system for sealing between the piston P-**1** and the surrounding spherical housing wherein a circumferentially extending ring seal **110** is disposed in a groove **111** which is substantially perpendicular to the axis of rotation P-1′ of the piston P-**1.** As shown, a pair of side seals **112** and **113** are provided on the piston P-**1,** which side seals are substantially the same as the side seals shown in FIGS. **10** and **11** with the exception of the alignment and location of such side seals with respect to the circumferentially extending seal **110.** As shown in FIG. **13,** the side seals **112** and **113** are disposed at an angle other than 90° with respect to the circumferentially extending seal **110** and are provided with plug seals **114** and **115,** respectively, which seal the juncture between such side seals and the circumferentially extending seal. The plug seals **114** and **115** are also substantially the same as the plug seals **95** shown in FIGS. **10** and **11.** With the FIG. **13** embodiment, there are thus provided two side seals **112** and **113** for sealing between the piston P-**1** and the pin end seal **20** on the journal **15** and also for sealing the piston P-**1** with respect to the outer surrounding housing H. As shown in FIG. **14,** the circumferentially extending seal **110** is provided with a lap joint **120** and, if desired, a pin **121** may be provided for locking the seal **110** in the groove **111** to thereby assure rotation of the seal **110** with the piston P-**1.**

Further, it will be understood that with each of the embodiments illustrating the various sealing systems of the present invention, such seals have been described with respect to the journal **15** on one side of the center piston P-**3** and also with respect to the piston P-**1.** However, it will be understood that the sealing systems described may also be used on the opposite side of the center piston P-**3** for sealing with respect to the journal **16** and also the piston seals may be used for sealing the piston P-**2.**

Considering now the compressor embodiment of the spherical displacement device shown in FIGS. **15-19** of the drawings, the housing designated generally H′ in FIG. **15** comprises two end sections **200** and **201** with spherical chamber portions C′ therein, which house the pistons P-**1,** P-**2** and P-**3.** In this embodiment of the invention, the housing H′ is surrounded by a cylindrical body or case **205** which has a circular rear end plate **205***a* which is welded or formed integrally with the case **205.** The case **205** is sealed with the front end section **200** by means of an O-ring **206** or other suitable sealing means. Also, an intermediate seal is formed by an O-ring or other suitable seal **210***a* which extends circumferentially between the exterior housing section **200** and the interior surface of the body or case **205** to provide a pair of sealed passages or manifolds **208** and **210** which serve as fluid inlet conduits and fluid discharge conduits, respectively.

The housing section **200** is provided with a neck **214** having a bore **215** therein for receiving suitable bearings **216** for mounting the shaft **218** of the piston P-**1.** The shaft is shown with a pully **219** keyed thereto for driving the piston P-**1.** Bearings **220** are mounted in the housing **200** for engaging a bearing race **221** formed at the outer edge of the piston skirt **223.**

Similarly, the piston P-**2** is provided with a shaft **225** that is mounted in suitable bearings **226** carried in a bore **228** in the housing portion **201.** Also, bearings **229** engage the bearing race **231** on the rear surface of the piston skirt **233** of the piston P-**2.**

As shown in FIG. **15** of the drawings, an inlet passage **235** is provided in the housing **201** for connecting a suitable fluid inlet line thereto. A one-way check valve **236** is provided at the passage **235** to prevent back flow through such inlet. In the preferred form of this invention, the check valve comprises a reed type check valve which includes a reed **237** and a reed stop **239.** The valve **236** opens only when there is a lower pressure in the manifold **208** than in the inlet passage **235.**

FIGS. **18** and **19** show the interior inlet passage **240** which communicates incoming gas, such as freon or the like, from the inlet manifold **208** to the spherical chamber C in which the pistons P-**1,** P-**2** and P-**3** are working. The passage **240** is formed in the housing section **200** and has a pair of spaced ports **241** and **242** for communicating opposite sides of the central piston P-**3.**

The discharge ports **250** and **251** are shown in FIGS. **18** and **19.** Such discharge ports communicate with discharge manifold **210** which extends circumferentially of the housing member **200.** Reed-type check valves **253** and **254** are provided for controlling one-way flow outwardly through the discharge ports **250** and **251,** respectively. Such reed-type check valves are similar to the reed-type check valve **236** mounted at the inlet port **235.** Such valves also include reed members **255** and an upper guide or stop **256** which is best seen in FIG. **19** of the drawings for limiting the travel of the reeds **255.** With this arrangement, compressed fluid such as freon discharged through the ports **250** and **251** into the discharge passage **210** is not allowed to back up into the spherical power device and a suitable discharge port **257** is provided in the cylindrical case **205** for connecting a tube or other conduit thereto.

As shown in FIG. **15** of the drawings, the piston P-**1** is provided with arcuate ring-type seals **270** and **271,** which are positioned in suitable grooves **272** and **273**

formed in the piston body adjacent the surfaces **5** and **6.** Such seals engage the spherical inner surface of the chamber C' as such piston rotates about its axis.

Similarly, bar or strip seals **277** and **278** are provided in suitable grooves **279** and **280,** respectively, which are formed adjacent the longitudinally extending semi-cylindrical groove which receives the split journal **15.**

Transversely extending seals **283** are provided in suitable slots or grooves shown adjacent the opposite ends of the split journal **16** for sealing it with respect to the adjacent piston. Also, the seal **283** seals the end of the journal **16** and the adjacent interior surface of the spherical chamber C', and also seals the ends of the cross seals **277** and **278.** Similar grooves and seals are provided also adjacent the opposite ends of the split journal **15.** Similarly, suitable grooves and seals such as those shown in the piston P-**1** are also provided in the piston P-2 for sealing it with respect to the spherical chamber C and also with respect to the journal **16.**

A pair of ring seals **285** and **286** are shown extending circumferentially of the central body portion of the center piston P-**3.** Such seals are positioned in suitable grooves **287** formed in such plate **25.** Thus, it will be appreciated that with the various seals provided in the pistons P-**1** and P-**2** as well as in the piston P-**3,** the compressor apparatus shown in FIG. **15** may be operated at pressures substantially in excess of atmospheric pressure.

The compressor shown in FIG. **15** is also provided with an oil pump **290** shown secured to the shaft portion **225** of the rotatable piston P-**2.** The oil pump **290** pumps oil through a central passage or bore **300** extending longitudinally of the shaft **225** into suitable oil conduits **301** for depositing oil on the curved surfaces of the split journal **16** and the adjacent surface of the piston. Other oil passages **303** are provided for conducting oil to the bearings **229.**

A passage **304** extends through the center of the plate **25** and also through the journal **15** for conducting lubricating oil to the longitudinally extending groove **308** in the piston P-**1** which lubricates the curved surface of the journal **15** and the curved surface of the piston and also for conducting oil through the passage **309** for lubricating the bearings **216.** The back bearings **220** are lubricated by an oil passage (not shown) similar to oil passage **303** that lubricates bearings **229.** Thus, with the apparatus of this invention positive pressure lubrication may be provided to many of the bearing surfaces for lubricating the device during its operation.

It will be appreciated and understood that the various sealing systems illustrated in FIGS. **1–14** of the drawings may be used in the type of compressor illustrated in FIGS. **15–19.** Similarly, the sealing system illustrated in this application may be used in other high pressure applications of the spherical displacement device other than compressors.

Another alternate embodiment of the present invention is shown in FIGS. **20** and **21** of the drawings wherein a spherical displacement device is provided in which one end piston is either formed integrally with or fixed against rotation in the spherical housing H. In this embodiment, the end piston P-**2''** is either formed integrally with or fixed against rotation relative to the chamber C in the housing H. Of course, in this fixed piston embodiment no seals are required between the piston P-**2''** and the surrounding housing; however, strip seals and pin end seals are provided for sealing between the journal on the center piston P-**3''** and the fixed end piston P-**2''**. The center piston P-**3''** is substantially identical to the center piston shown in the FIG. **1** embodiment.

As shown in FIGS. **20** and **21,** the other end piston P-**1''** is shown rotatably mounted on a crank shaft **400** which is inclined relative to the axis P-**1** and which is mounted eccentrically with respect to such axis on a rotating shaft **402** which is rotatably mounted so as to turn on the axis P-**1.** As shown in the drawings, such shaft **402** is mounted in suitable bearings **404.**

As shown in FIG. **21** of the drawings, the inclined crank shaft **400** described a cone indicated by the number **406** as such inclined shaft rotates through the circle **407** around the axis P-**1.**

Rotation of the shaft **402** in a clockwise direction as viewed from the right hand end of FIG. **20** of the drawings causes the center piston P-**3''** to oscillate back and forth between the fixed end piston P-**2''** and the nutating piston P-**1''** and further, such rotation of the shaft **402** causes the inclined or crank shaft **400** to rotate in the opening in the piston P-**1''** so as to cause reciprocal motion between the end piston P-**1''** and the center P-**2''**.

Thus, it will be appreciated, that the effect of the relative motion between the fixed end piston P-**2''**, the oscillating center P-**3''** and the nutating end piston P-**1''** will be substantially the same as the effect of the relative motion between the pistons P-**1,** P-**2** and P-**2** shown in the FIG. **1** embodiment, i.e., positive displacement of fluid in the respective chambers formed between such pistons will be effected. Further, it will also be appreciated that the seal means used for sealing the pistons P-**1''** and P-**2''** with respect to each other and with respect to the surrounding housing as well as with respect to the end piston P-**2''** will be substantially identical as the seal means illustrated in conjunction with the other embodiments shown herein. Further, fluid flow through inlet and discharge ports for each chamber formed between adjacent piston faces is controlled by check valves **410.**

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape, and materials as well as in the details of the illustrated construction may be made without departing from the spirit of the invention.

What is claimed is:

1. In a spherical displacement device having a plurality of variable volume chambers for use as a pump, compressor or motor comprising a housing having a cavity therein, at least a portion of which has a substantially spherical configuration, a pair of end pistons disposed in said spherical cavity, each of said end pistons being mounted for rotation in said spherical cavity about an axis of rotation, the axis of rotation of each of said pair of end pistons being disposed at an angle other than 180° with respect to the other axis of rotation, each of said pair of end pistons having a pair of faces inclined axially inwardly toward the center of said spherical cavity, first semi-cylindrical journal means in each of said pair of pistons extending diametrically of said spherical cavity, a central piston disposed in said spherical cavity between said pair of end pistons and extending diametrically of said spherical chamber, said central piston having a second semi-cylindrical journal

means on opposite sides thereof for operably connecting said first semi-cylindrical journal means of each of said pair of end pistons and a pair of piston faces on each side of said second journal means aligned with said inclined piston surfaces to form a plurality of chambers in said spherical cavity whereby said central piston is simultaneously oscillated as it rotates with said pairs of pistons to vary the volume of said plurality of chambers, an improved sealing arrangement for sealing between said end pistons, said central piston and said spherical housing comprising:

a. semi-cylindrical end seal members on opposite ends of the semi-cylindrical journal means on said central piston and positioned externally of said semi-cylindrical journal with the ends of said semi-cylindrical end seals received in slots in said center pistons adjacent said semi-cylindrical journal means; and

b. arcuate ring seal segments disposed in grooves extending circumferentially of said center piston between said semi-cylindrical end seal members.

2. The invention of claim **1** wherein said arcuate ring segment seals have tapered ends adjacent said semi-cylindrical end seal members and including wedge-shaped lock means positioned between said tapered ends of said arcuate ring seal segments and said semi-cylindrical end seal members for limiting longitudinal movement of said arcuate ring seal segments in their grooves upon rotation of said center piston in said spherical chamber and for sealing between said semi-cylindrical end seal members and said tapered end segments adjacent thereto to prevent leakage of pressure from behind said arcuate ring seal segments.

3. The invention of claim **1** including plug seal means provided at the juncture of said semi-cylindrical end seal members and said arcuate ring seal segments with slot means provided in said plug means for receiving said arcuate ring segment seals with said center piston being provided with suitable openings for receiving said plug seal means whereby high pressure gas in said circumferentially extending grooves is prevented from leaking around said center piston.

4. The invention of claim **3** including fluid passage means in said end piston for communicating high pressure fluid to the opening in said end piston in which said plug means is received for urging said plug means outwardly into said sealing engagement with said arcuate ring segment seal.

5. The invention of claim **3** wherein spring means are provided in said openings in said center piston for urging said plug seal means radially outwardly.

6. The invention of claim **5** wherein said plug seal means includes a hollow tubular member having a notch formed in its outer end for receiving said ring seal means and having a movable piston disposed in said hollow tubular member adapted to engage the inner surface of said ring seal means and having spring means for urging said piston means and said tubular member radially outwardly into sealing engagement with said ring seal means.

7. In a spherical displacement device having a plurality of variable volume chambers for use as a pump, compressor or motor comprising a housing having a cavity therein, at least a portion of which has a substantially spherical configuration, a pair of end pistons disposed in said spherical cavity, each of said end pistons being mounted for rotation in said spherical cavity about an axis of rotation, the axis of rotation of each of said pair of end pistons being disposed at an angle other than 180° with respect to the other axis of rotation, each of said pair of end pistons having a pair of faces inclined axially inwardly toward the center of said spherical cavity, first semi-cylindrical journal means in each of said pair of pistons extending diametrically of said spherical cavity, a central piston disposed in said spherical cavity between said pair of end pistons and extending diametrically of said spherical chamber, said central piston having a second semi-cylindrical journal means on opposite sides thereof for operably connecting said first semi-cylindrical journal means of each of said pair of end pistons and a pair of piston faces on each side of said second journal means aligned with said inclined piston surfaces to form a plurality of chambers in said spherical cavity whereby said central piston is simultaneously oscillated as it rotates with said pairs of pistons to vary the volume of said plurality of chambers, an improved sealing arrangement for sealing between said end pistons, said central piston and said spherical housing comprising:

arcuate ring segment seals disposed in grooves in said end pistons with the ends of said arcuate ring segment seals tapered to a point and strip seal means extending axially of said semi-cylindrical journal means in each of said end pistons with the ends of said strip seal means being tapered to interfit with the tapered ends of said arcuate ring segment seals and with spring means for urging said tapered ends of said strip seal means into engagement with said tapered ends of said arcuate ring segment seals.

8. The invention of claim **7** wherein said arcuate ring segment seals are disposed in grooves substantially parallel to the inclined faces of said end pistons.

9. The invention of claim **7** wherein said arcuate ring segment seal is disposed in a continuous groove extending circumferentially of said end piston and in a plane which is not perpendicular to the axis of rotation of said piston.

10. The invention of claim **7** including side seal means which are disposed in grooves substantially perpendicular to said arcuate ring segment seals with wedge-shaped seal means disposed between the ends of said arcuate ring segment seals and said side seal means.

11. The invention of claim **7** wherein said side seal means are provided with wedge-shaped seal means adjacent the first semi-cylindrical journal means on said central piston for engaging the semi-cylindrical end seal members on the semi-cylindrical journal means on said central piston.

12. The invention of claim **11** including spring means for urging said wedge-shaped seal means outwardly between said side seal members and the adjacent semi-cylindrical end seal member on said semi-cylindrical journal means on the central piston.

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