Feb. 13, 1973 W. D. GUENTHER 3,716,310

DIRECT DRIVE BALL PISTON COMPRESSOR

Filed Jan. 20, 1971 3 Sheets-Sheet 1

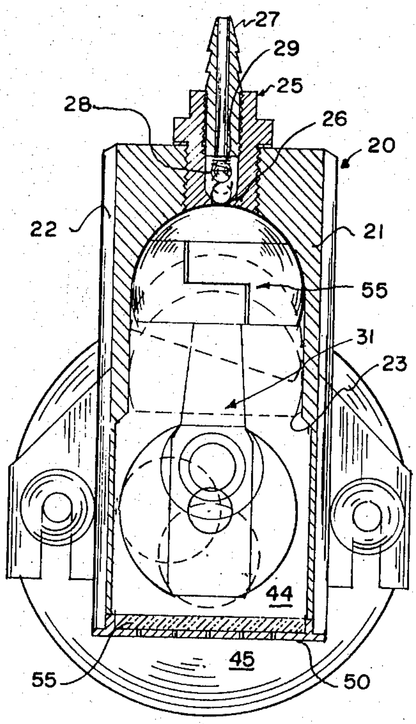

FIG 1

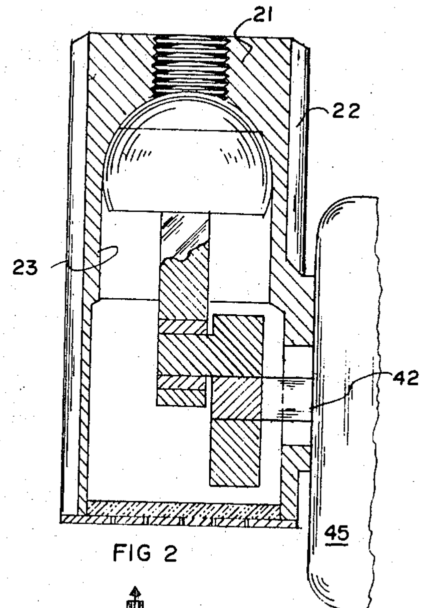

FIG 2

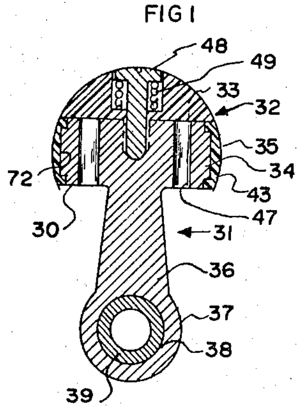

FIG 5

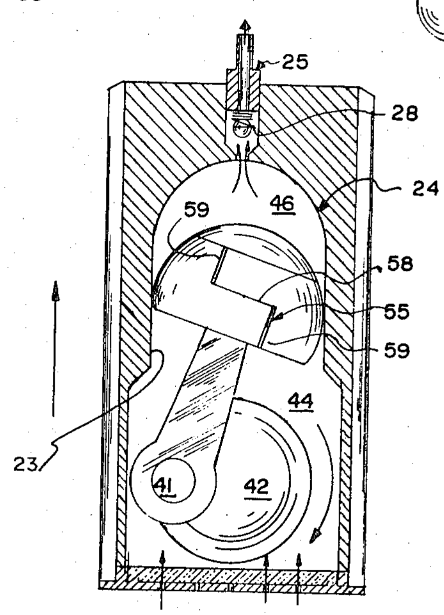

FIG 4

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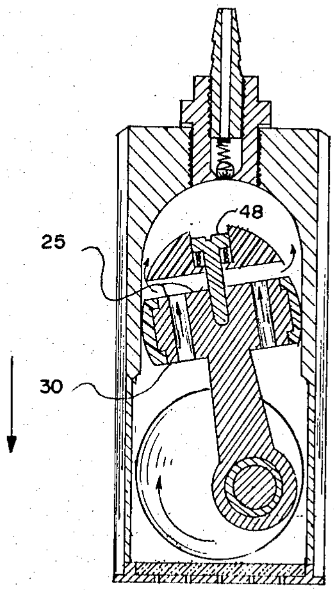

FIG 3

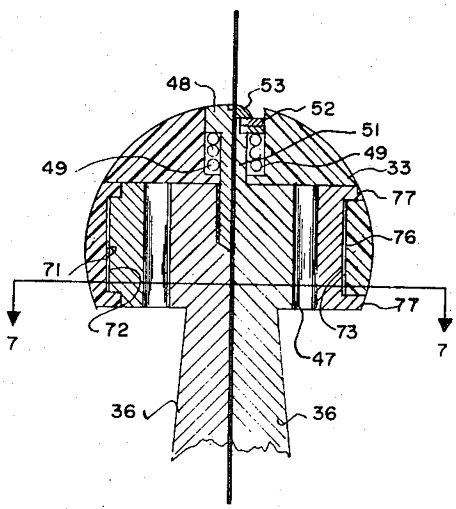

FIG 6

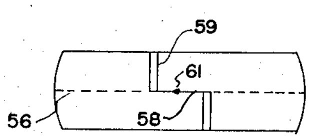

FIG 8

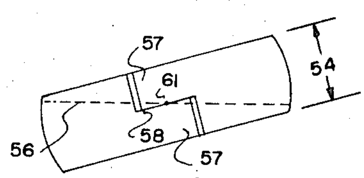

FIG 9

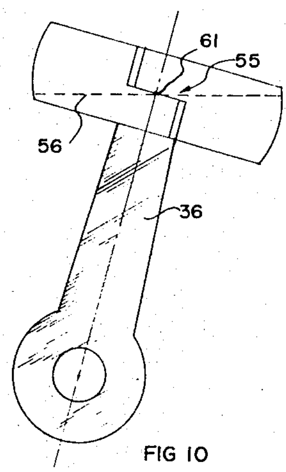

FIG 10

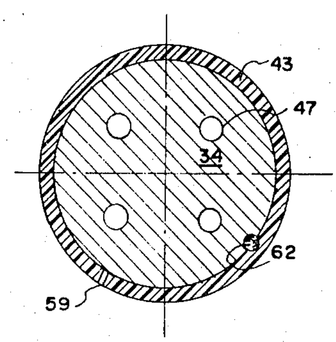

FIG 7

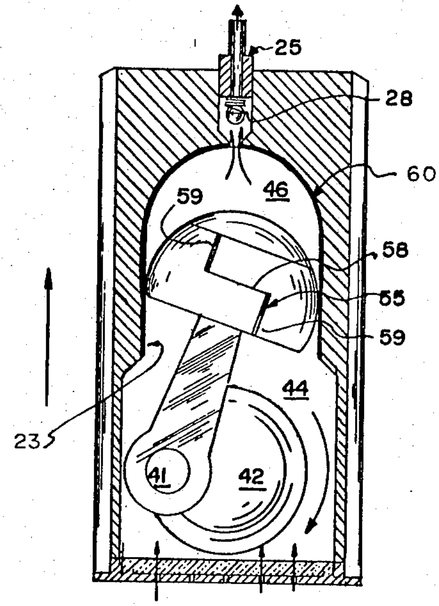

FIG 11

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DIRECT DRIVE BALL PISTON COMPRESSOR

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Int. Cl. F04b *21/04;* F16j *1/00*
U.S. Cl. 417—552 6 Claims

ABSTRACT OF THE DISCLOSURE

A compressor including an essentially spheroidal piston having a biased spheroidal crown member acting as a valve and mating with a cupola shaped cylinder head.

This invention relates to a compressor and more particularly a compressor using a spheroid as a piston in the compression chamber.

In fluid compressors, particularly air compressors, compression is normally obtained by the use of reciprocating cylindrical piston within the compression chamber supplemented by piston rings and associated valves. In all but specialized instances these types of compressors require a significant amount of oil for lubrication.

It has been found that an efficient, light-weight, and physically smaller compressor than conventional compressors can be achieved by using a novel piston configuration essentially spheroidal. The piston head portion of the piston and the rod portion are rigidly connected to one another. Moreover, valves are provided in the head portion for the removal of fluid through it and the profile of the head portion in combination with the cylinder head are such that static fluid disposed between the upper surface of the head portion of the piston and the cylinder head is removed when the piston is at its upper stationary position during the terminal part of the compression stroke.

The invention therefore contemplates a fluid compresor including a power shaft, a cylindrical compression chamber having a cupola shaped cylinder head with apex to create a void, and valve means communicating through said cupola shaped cylinder head with said chamber such that fluid within the compression chamber may be ejected therethrough, and a piston, said piston comprising an ellipsoidal-like shaped head portion with an upper arcuate crown member and a lower truncated skirt portion with upper and lower surfaces and convex perimeter, and a rod portion rigidly connected to said skirt portion, said skirt portion having a channel therethrough communicating the upper surface thereof with the lower surface thereof, the convex perimeter corresponding to the loci of the surface of a spheroid having a diameter corresponding to that of the compression chamber such that a circumscribing margin about the convex perimeter is adapted to frictionally engage the walls of the chamber during reciprocating oscillations of the piston, the arcuate upper crown member biasingly engaging the upper surface of the lower truncated skirt portion to mate therewith but adapted to disassociate from the skirt portion and to expose said channels during intake strokes of said piston, said crown member having its convex surface of ellipsoidal-like shape corresponding to the cupola shape of the cylinder head.

The embodiments of the invention will now be described by way of example, reference being had to the accompanying drawings in which;

FIG. 1 is a cross sectional view of one embodiment of the invention, the piston disposed at the terminal portion of its compression stroke.

FIG. 2 is an end view of the compressor of FIG. 1 partially in section, valve means removed.

FIG. 3 is a cross-section of the chamber and piston, the piston disposed approximately halfway through the intake stroke.

FIG. 4 is identical to FIG. 1, the piston disposed halfway through the compression stroke.

FIG. 5 is a section through the piston of FIG. 1.

FIG. 6 is a comparative cross-section of the head portion of the piston showing two embodiments of ring configurations, and of spring retaining devices.

FIG. 7 is a cross-section along lines 7—7 of FIG. 6.

FIGS. 8, 9 and 10 are representative explanatory drawings of the ring in its various disposed positions during piston cycling with the circumscribing margin indicated as a dash line.

FIG. 11 being identical to FIG. 4 but disclosing a coating within the compression chamber.

Referring to FIG. 1 a compressor **20** includes an outer metal housing **21** with appropriate cooling fins **22** and cylindrical compression chamber **23**. The compression chamber **23** has a cupola like cylinder head **24** of preferably spherical configuration, with apex (to create a void), the diameter of which is fractionally larger than the corresponding diameter of an upper crown member **33** to be later described. A valve means **25** including a small orifice **26** communicates the apex of the cylinder head **24** to a nipple **27** mounted on the housing **21** for subsequent communication to a reservoir (not shown). Disposed between the nipple **27** and the orifice **26**, to provide sealing of the orifice, is a ball **28** biased by a spring means **29**.

A piston **31** includes a head portion **32** of truncated spherical shape having an upper crown member **33** of arcuate profile and a lower truncated skirt portion **34** with upper and lower surfaces **15** and **30**, and a convex perimeter **35**. The lower skirt portion **34** is rigidly connected to one end of a rigid piston rod **36** while the other end of the rod **36** has a protuberance **37** thereon with orifice **38**. The orifice **38** accommodates a bearing bushing **39** of suitable type for connection to the throw arm **41** of a powershaft **42**. The powershaft **42** is connected to an appropriate prime mover **45** such as an electric motor. The convex perimeter **35** preferably is a circumscribing ring **43** which is mounted on the skirt portion **34** by appropriate means to be described later.

Referring to FIG. 5 the skirt portion **34** is preferably dish shaped accommodating the upper and lower surfaces **15** and **30**. Channels **47** communicate through the skirt portion to provide a passage for fluid from its lower surface **30** to its upper surface **15** for reasons which will become apparent. The upper crown member **33** biasly engages the upper surface **15** to sealingly close the channels **47** but is adapted to disassociate from the upper surface **15** during the intake stroke of the piston **31** to thereby openly expose the channels **47** such that fluid can pass through the channels from the lower portion **44** of the compression chamber **23** to the upper portion **46** thereof as more particularly illustrated in FIG. 4. In order to ensure contaminates do not enter the lower portion **44** of the compression chamber **23** a porous plate or screen **50** is provided across the lower extremely of the lower portion of the compression chamber **23**. Filtering of the fluid entering the lower portion **44** from the elements is enhanced by the use of a gauze **65** or other suitable filtering media.

Referring to FIG. 6 the biasing of the upper crown member **33** to the upper surface **15** may be accommodated by (referring to the left side of FIG. 6) a flat head screw **48** with underlying spring means **49**. Alternatively, it has been found that fabrication during mass production can be simplified if the skirt portion **34** is constructed such that it has a stem **51** projecting from the upper surface **15** coincident with the axis of the piston **31**. The spring means **49** is mounted about the stem **51** and washers **52** are placed over the spring means **49**. The stem **51** is then peened down in the usual manner to form a rivet type retaining lip **53**. (See right hand of FIG. 6).

The operation of the compressor is as follows: The powershaft **42** rotates clockwise and causes the throw arm **41** to move the piston **31** up and down within the compression chamber **23**, in the following sequence. Referring to FIGS. 1 and 2 the piston **31** is disposed within the chamber at the terminal portion of the compression stroke (dead stop position). As the powershaft **42** rotates 90 degrees (FIG. 4) the piston **31** is caused to be pulled downward in the chamber **23** while also being tilted to the left as shown. Such tilting results because of the fact that the piston **31** is rigid, that is there is no wrist pin between the head portion **34** and the rod portion **36**. The titling is further accommodated by the convex perimeter **35** which describes the locus of the surface of a spheroid whose diameter is equal to that of the compression chamber 23. Referring to FIGS. 8, 9 and 10, the width of the convex perimeter **35**, more correctly the length of the chord **54** which subtends the convex perimeter, is such that the degree of tilt is accommodated. In other words, the circumscribing margin of contact **56** between the convex perimeter **35** and the walls of the compression chamber **23** always defines itself on the surface of the convex perimeter **35**.

During the intake stroke, the valve means **25** stops shut the orifice **26** and a vacuum exists in the upper portion **46** (that part of the compression chamber between the apex and the piston head **32**). As a result fluid in the lower portion **44** of the compression chamber **23** is drawn through the channels **47**, into the upper portion **46** as shown. During this stroke, the crown member **33**, disassociates itself from the skirt portion **34** to expose the channels **47**, and to thereby permit the fluid to flow.

As the powershaft **42** rotates to 180 degrees the piston **31** is drawn further down into the chamber **23** to its full extent. Also it is tilted back into its vertical position. In its dead stop position the spring means **49** urges the crown member **33** back into mating contact with the upper surface **15** to thereby sealingly close the channels **47**. As the powershaft moves towards the 270 degree position the piston **31** starts its upward compression stroke tilting to the right (FIG. 4). Fluid which is disposed in the upper portion **46**, between the crown member **33** and the cylinder head **24**, is forced through the valve means **25** (the ball **28** being displaced as shown in FIG. 4) into the reservoir (not shown). When the 360 degree position is reached the ball **28** is urged back to close the orifice **26**. The cycle is then repeated.

Referring in greater detail to the construction of components of the compressor **20**, although the ring **43** may be unitary, that is in the form of a solid annulus, in order to accommodate thermal expansion under severe operating conditions, the ring **43** preferably has a lap seam **55** consisting of two correspondingly dependent fingers **57** (FIG. 9) which form a juncture **58** in a plane coincident to the plane perpendicular to the axis of the ring. The fingers **57** expose at the extremities thereof an aperture **59** to accommodate the expansion and contraction of the ring **43** as a result of thermal change. It has been found that because the width **54** of the ring ring **34** is quite small as compared to its length (perimeter) the fingers **57** may be juxtaposed one to another so that the juncture **58** is for all practical purposes a seal and yet permit a reasonable size aperture **59**.

Now referring to FIGS. 8, 9 and 10 it will be seen that the ring **43** is disposed on the lower skirt portion **34** such that the centre of the juncture **58** rests on the pivot axis **61** of the piston head **32**. Alternatively, the juncture **58** may be described as being intersected (preferably bisecting the juncture 58) at right angles by the plane which intersects both the axis of the piston rod portion **36** and the axis **61** of rotation of the piston **31**. It will be appreciated that if the juncture **58** is not disposed such that the axis of rotation **61** rests on the juncture **58**, that loss of sealing across the circumscribing margin of contact **56** between the convex perimeter **35** and the walls of the compression chamber **23** will take place. This can be fully appreciated on careful study of FIGS. 8, 9 and 10.

Referring to FIG. 7, the juncture **58** may be retained in the position such that the pivot axis **61** interescts it, by an appropriate holding means such as a hold rod **62** disposed between the ring **43** and the lower skirt portion **34**.

As will now be appreciated the disposition of the juncture **58** in the manner described insures that no fluid passes between the convex surface **35** and the walls of the cylinder **23**, during any portion of the operating cycle of the compressor, especially during the vital compression stroke. Further, in order to improve the sealing contact of the convex surface **35** with the walls of the cylinder **23** it has been found that preferably the composition of the ring **43** should be soft and pliable but wear resistant. It has been found that a suitable material includes tetrafluoride composition such as Teflon, Teflon bronze, glass-filled Teflon and the like. Nevertheless the actual composition for any particular compressor depends upon the wall characteristics of the chamber **23**. Teflon and Teflon bronze have been found to be satisfactory where the housing **21** is composed of cast steel and the walls of the chamber **23** have been honed, for example, 16 to 24 microns. Alternatively, if the housing is made of cast zinc, it has been found that by standard copper plating techniques the walls of the compression chamber **23** can be plated with copper, and thereafter plated with a thin coating (0.0005" to 0.0001") of nickel which provides a porous and visually dull surface to the walls of the compression chamber **23**. When a ring material of Teflon bronze or for high durability of the ring material, glass-filled Teflon is used, excellent wear resistant properties for the ring are achieved. Further it has been found that glass-filled Teflon is an extremely good material for the upper crown member **33**.

Now referring again to FIG. 6 the ring **43** and skirt portion **34** may have different profiles. Referring to the left hand portion of FIG. 6 the ring has an interior profile of that of a groove or channel **71** while the skirt portion has a radially extending tongue **72** which fits into the groove **71**. Alternatively, referring to the right hand portion of FIG. 6, the skirt portion may have a radially extending groove **73** while the ring may have a flat profile **76** as shown. In this embodiment of the ring and skirt portion, the skirt portion **34** has radially extending arms **77** which accommodate the ring **43**, the tips of which are arcuate and somewhat recessed from the loci traced by the surface of a spheroid the convex perimeter **35** is coincident.

It has been found that if the diameter of the spheroid is selected to be one inch, and hence the diameter of the piston head portion, and the length of the piston compression stroke is selected to be three quarters of an inch the compressor disclosed can pump air to a pressure in the neigbourhood of 115 p.s.i. providing of course a sufficiently powerful prime mover **45** is attaced to the powershaft **42**. Further, if larger bore compression chambers **23** are used, for example 2" bores, it has been found that the self resilience of the ring **43** is insufficient to constrain the ring 3 against the walls of the compression chamber **23** to ensure good compression. As a result it is desirable to insert between the ring **43** and the skirt portion **34** an encircling spring member (not shown) adapted to urge the ring **43** radially outward against the walls of the chamber **23**.

Although the housing of FIG. 4 is satisfactory, it has been found that in order to accommodate mass production in the casting of the housing **21**, the housing preferably is provided with a threaded channel **78** communicating with the apex of the compression chamber **23** as shown in FIG. 2.

Into this threaded channel **78** the valve means **25** is threaded. In order to ensure maximum displacement of static air in the upper portion **46** of the compression chamber **23** during the compression stroke, the valve means **25** has its face **79** shaped into cupola to accommodate the upper part of the upper crown member **33** as shown in FIGS. 1, 2, 3 and 4.

Now referring to FIG. 11 the compression chamber **23** has on the interior surface thereof a thin coating **60** of wear resistant material. Preferably, the wear resistant material is a zinc compound. More particularly, the zinc compound is a zinc anodised coating or what is commonly called anodic film on zinc from electroytes containing one or more anions from the group of "glass forming" elements—B, Al, Si, or P, plus one or more anions from a group of elements such as Cr, Mn, V or Mo. More particularly sodium silicate-chromate (SSC), sodium silicate-chromate-vanadate (SSCV) and sodium silicate-chromate-manganate (SSCMn) electrolytes for anodising zinc have been used. The electrolytic salts and the processes for producing protective coating on articles formed with or coated with zinc and zinc based alloys is commercially available under the trademark "Iridizing" by Chemical Processing Incorporated of Detroit, Mich., United States of America. Further, these processes have been disclosed in a certain patent by Arnold G. White in "Anodic Treatment of Zinc and Zinc-Base Alloys" issued in Canada as Pat. No. 605,265 on the 13th day of September 1960 and in the United States of America as Pat. No. 3,011,958 and in the United Kingdom as Pat. No. 876,127. More particularly, such coating having a range of thickness of 0.0075 to 0.0015 inch, particularly 0.0040 inch provides a satisfactory anodic zinc protective coating, **60**, on the walls of the zinc alloy, or coated zinc walls of the compression chamber **23** and as a result improves the wear resistance of the chamber **26** particularly from corrosion, erosion, abrasion and also reduces the friction of the tetrafluoride composition circumscribing ring **43** on the walls of the compression chamber **23**.

In order to improve "wear-in" of the compression ring, with the walls of the chamber **23** a grease may be applied to the walls of the compression chamber. Such satisfactory grease known as "Shell Cyprina No. 3 (GEL)" manufactured and sold by the Royal Dutch Shell Oil Company and its subsidiaries has been found satisfactory.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A fluid compressor including a power shaft, a compression chamber with a circular cross section having cylindrical walls and a cupola shaped cylinder head with apex to create a void, a channel including a valve means therein communicating through said cupola shaped cylinder head with said chamber such that fluid within the compression chamber may be ejected therethrough, and a piston, said piston comprising an essentially hemispherical shaped head portion with an upper arcuate crown member and a lower truncated skirt portion which corresponds to a diametrically symmetrical slice from a sphere with a diameter corresponding to the diameter of the great circle of the skirt portion to dispose a convex perimeter between upper and lower surfaces; a rod portion rigidly connected to said skirt portion, said skirt portion having a channel therethrough communicating the upper and lower surfaces thereof, the diameter of the great circle of the skirt portion corresponding to that of the compression chamber such that a circumscribing margin about the convex perimeter is a circle adapted to frictionally engage the walls of the chamber during reciprocating oscillations of the piston, a biasing means for biasingly engaging the upper crown member with the upper surface of the lower truncated skirt portion to mate said upper crown member and said truncated skirt portion but adapted to dissasociate from the skirt portion and to expose said channel during intake strokes of said piston, said crown member having its convex surface of spheroidal shape corresponding to the cupola shape of the cylinder head and said upper surface of the lower truncated skirt portion being located above said circumscribing margin of the skirt portion so that the surface of the crown member does not frictionally engage the walls of the compression chamber during reciprocating oscillations of the piston.

2. The compressor of claim **1** wherein the piston in its dead stop position at the terminal part of its compression stroke occupies the void created by the cupola shaped cylinder head such that virtually all the static fluid disposable between the cylinder head and the upper crown member is disposed from the void.

3. The compressor of claim **2** wherein the convex perimeter consists of an annular ring of soft, wear-resistant material.

4. The compressor of claim **2** wherein the convex perimeter consists of an annular ring having a lap seam for thermal expansion and contraction thereof, said lap seam including two juxtaposed fingers of the ring, establishing a juncture seal between the fingers, said juncture disposed in a plane coincident to a plane perpendicular to the axis of the piston, while the extremities of the fingers expose an aperture to accommodate linear expansion of the ring, said ring held by a holding means, to retain the juncture of the lap seam such that it is intersected at right angles by the plane which intersects both the axis of the piston rod portion and the axis of rotation of the piston.

5. The piston of claim **4** wherein the axis of rotation of the piston bisects the juncture of the lap seam of the ring.

6. The compressor of claim **5** wherein the ring consists of a tetrafluoride composition selected from the class consisting of polytetrafluoroethylene, polytetrafluoroethylene-bronze and glass-filled polytetrafluoroethylene.

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