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Pawelski et al.

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(54) **VARIABLE DISPLACEMENT COMPRESSOR WITH STEPPED SHAFT**

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(22) Filed: **Mar. 1, 2002**

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(51) **Int. Cl.**[7] **F04B 1/26**
(52) **U.S. Cl.** **417/222.1**; 91/499
(58) **Field of Search** 417/222.1, 222.2, 417/269, 53; 92/12.2, 71; 91/499, 505; 123/56.3, 56.4

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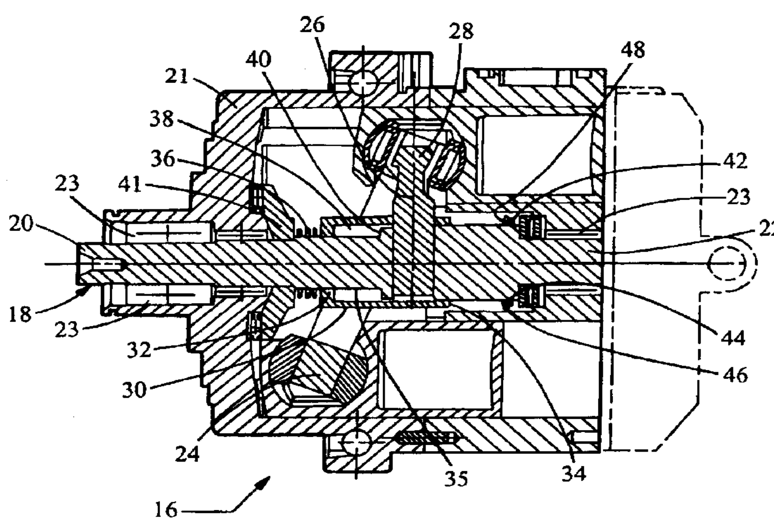
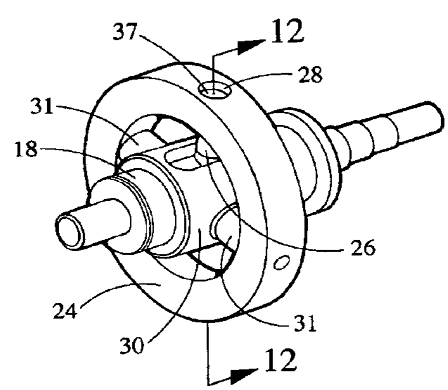
(57) **ABSTRACT**

A variable displacement piston compressor comprising a housing and a shaft supported within the housing for rotational movement about an axis. The shaft includes a stepped down portion defining a reduced diameter within the shaft. A pin extends generally outward from the shaft and includes a distal end. A sleeve is mounted about the shaft, is slidable along the shaft, and is rotatable with the shaft. The sleeve extends over a portion of the stepped down portion of the shaft and defines a radial gap between the sleeve and the stepped down portion. A swash-ring is supported on the sleeve and is rotatable with the shaft. The swash-ring is pivotably coupled to the distal end of the pin. The swash-ring defines an angle with the axis that is adjustable with respect to the axis. A biasing member engages the sleeve and biases the sleeve along the shaft.

17 Claims, 6 Drawing Sheets





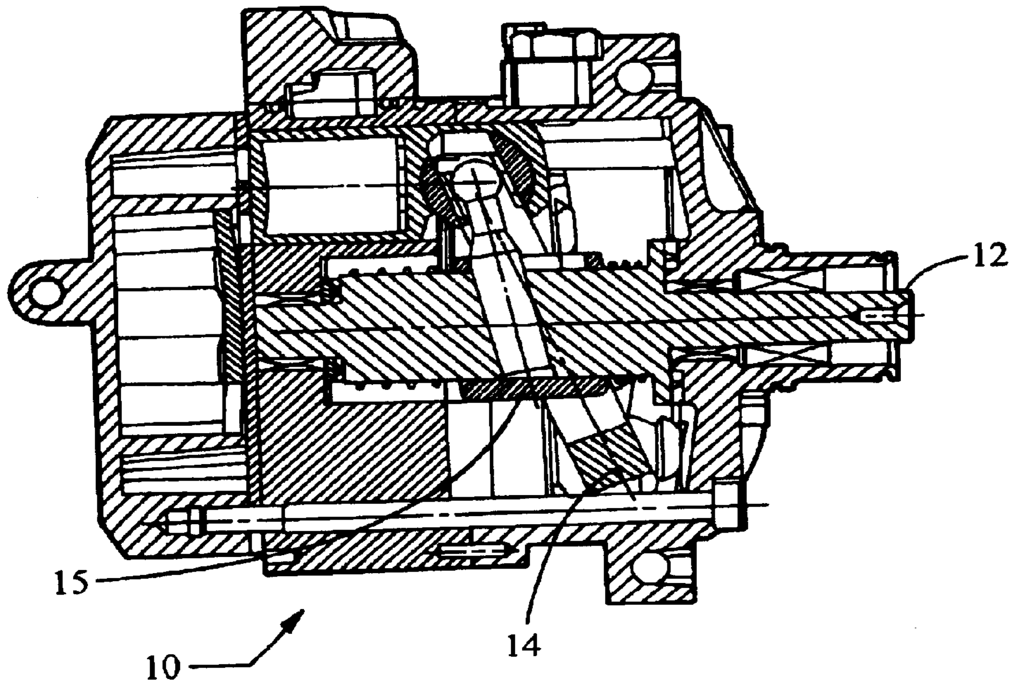


Fig. 1
Prior Art

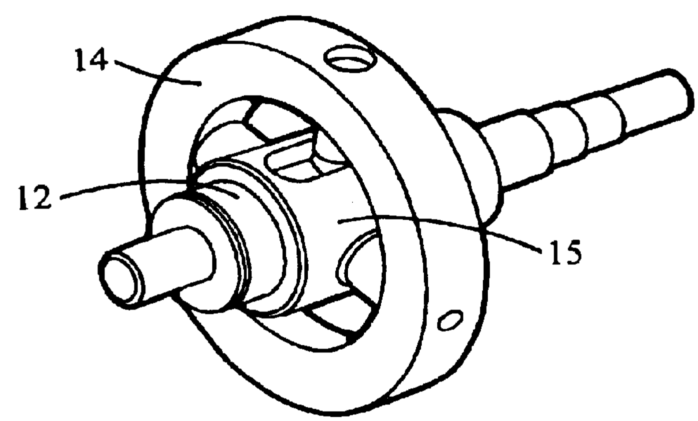


Fig. 2
Prior Art

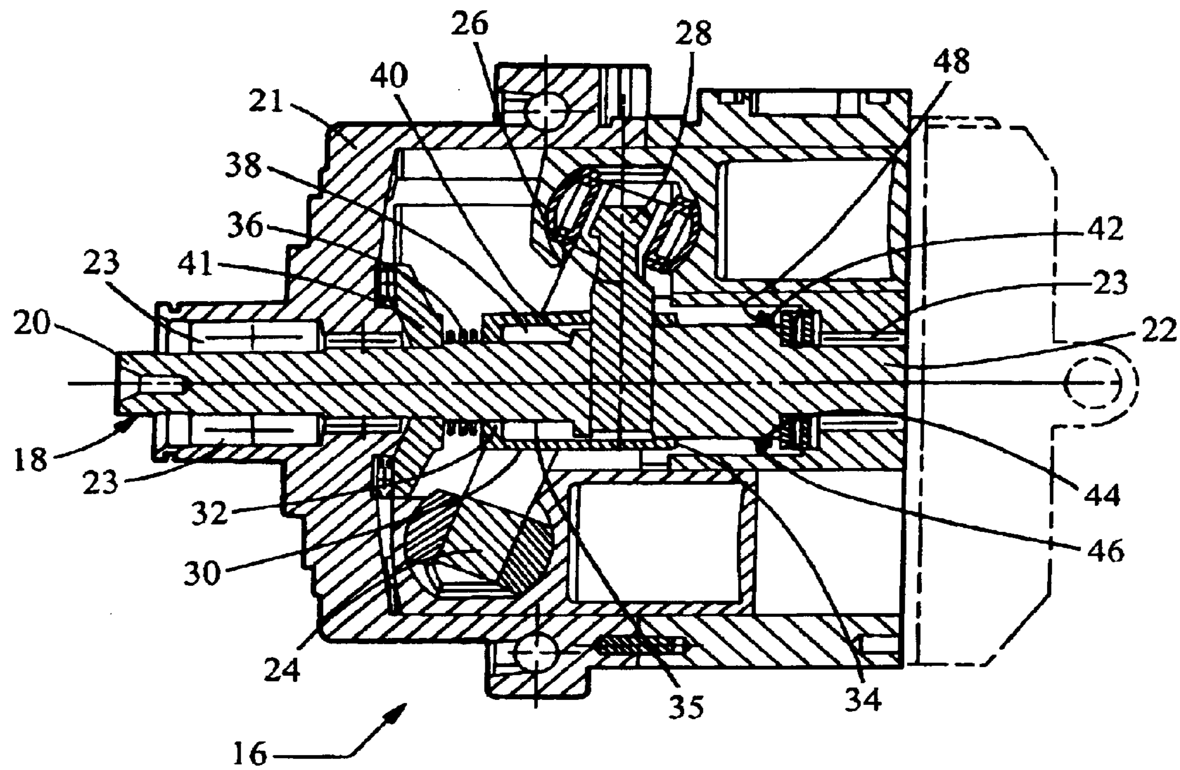

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Fig. 3

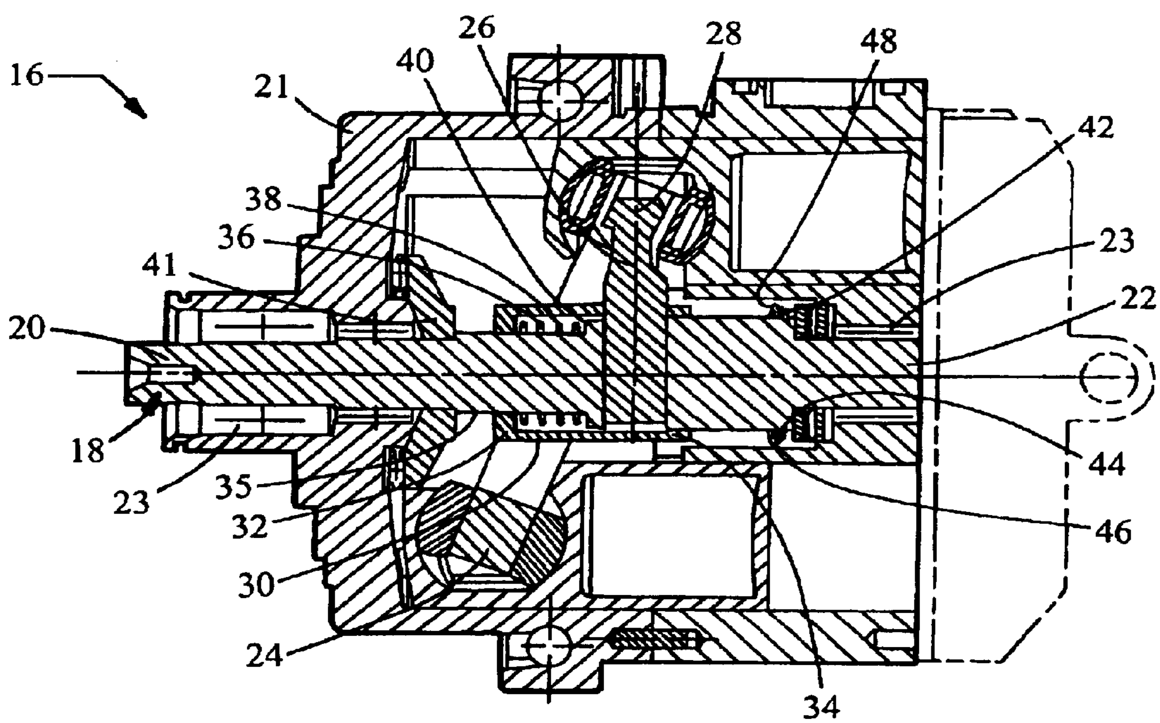
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Fig. 4

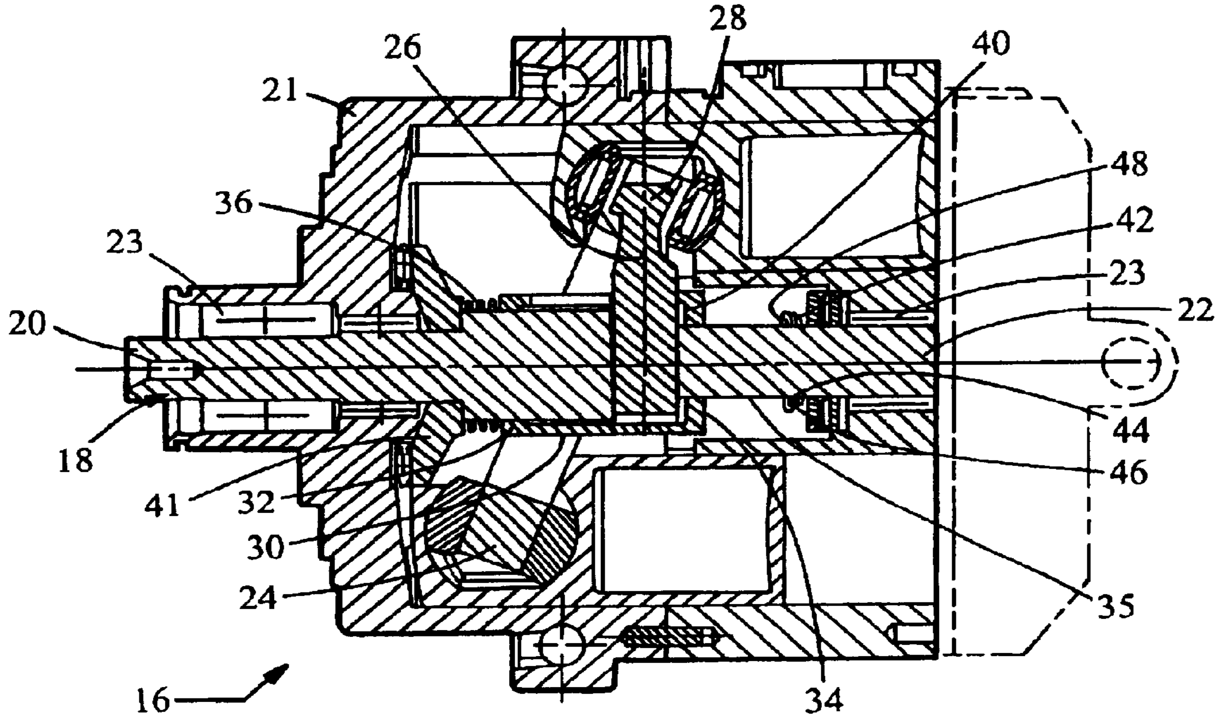
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Fig. 5

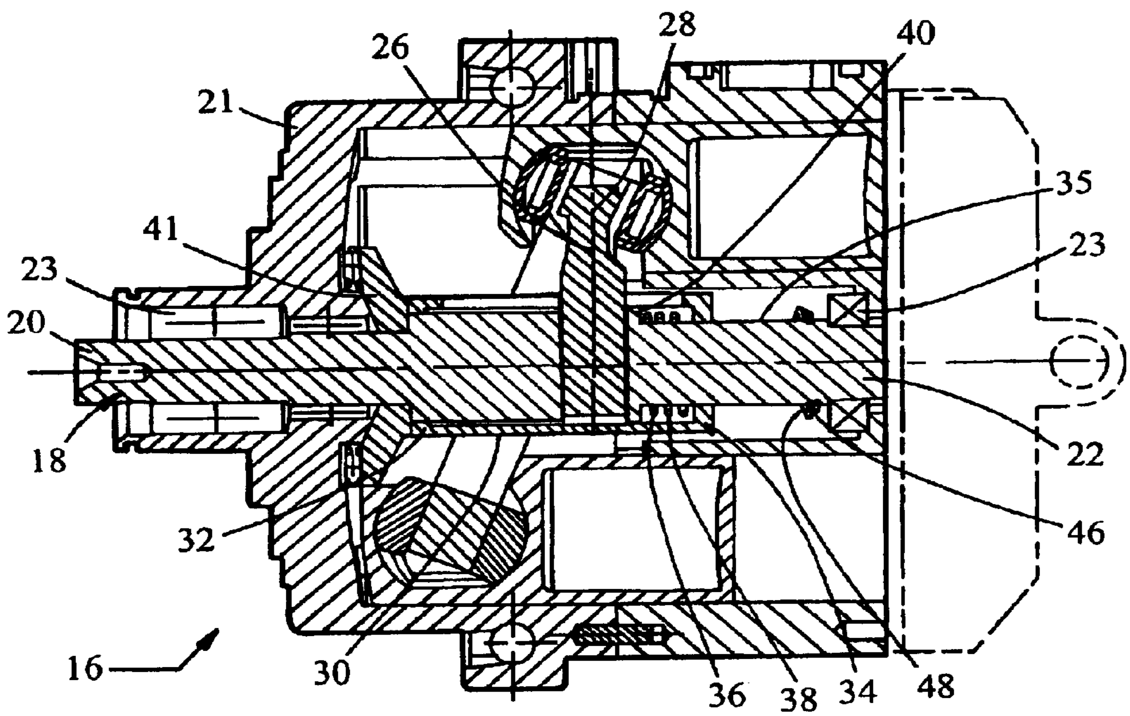
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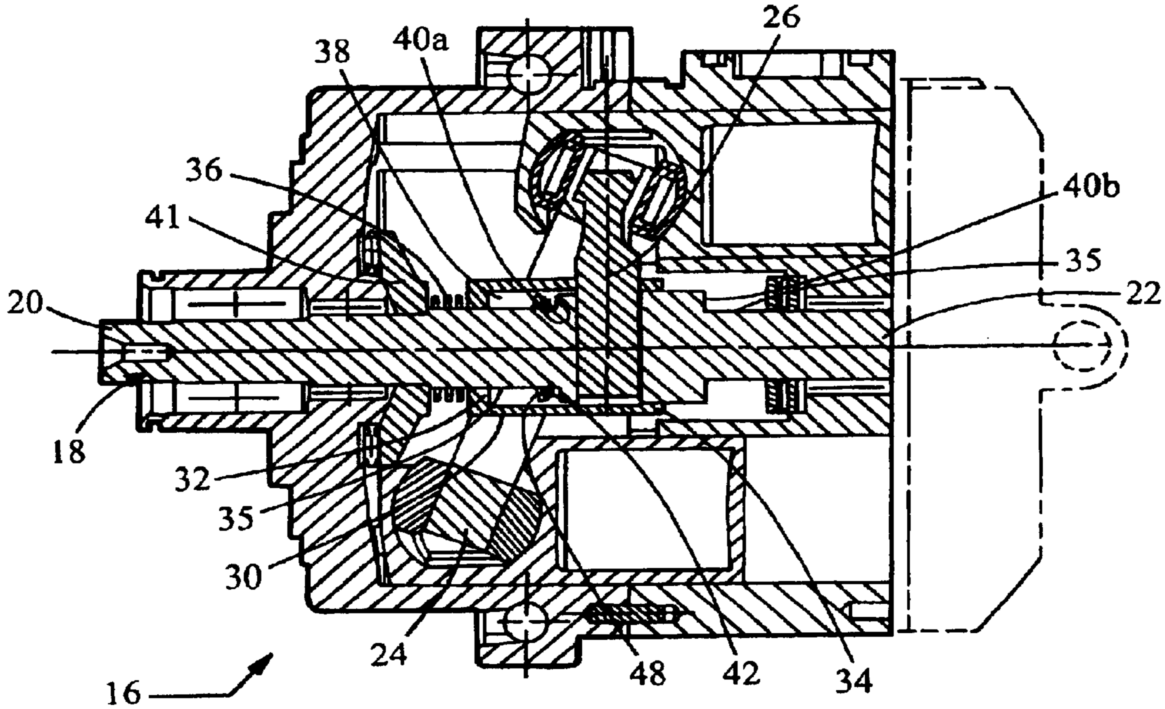
Fig. 6



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40a
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40b
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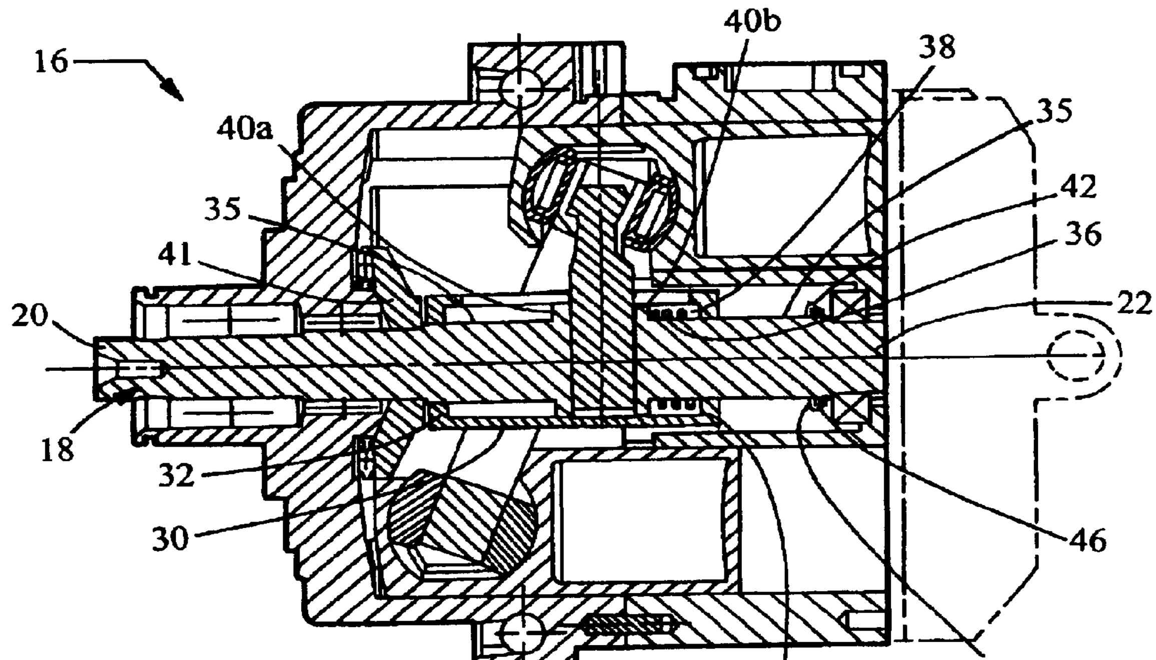
Fig. 7



40b
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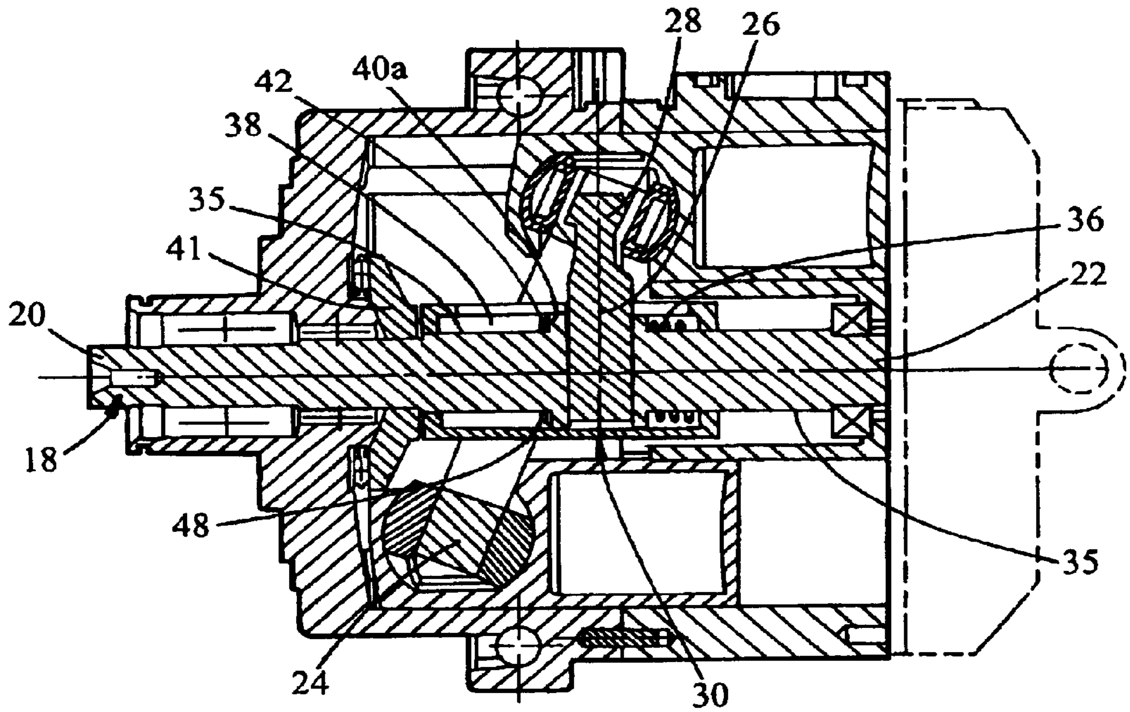
Fig. 8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40a
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Fig. 9

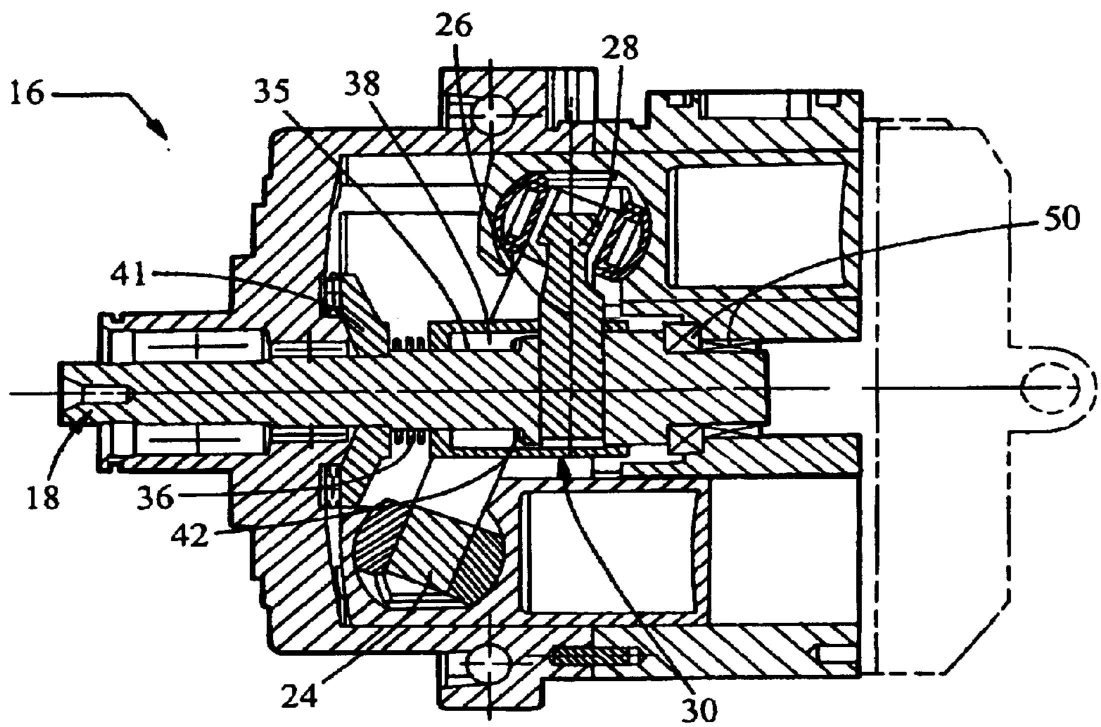
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Fig. 10

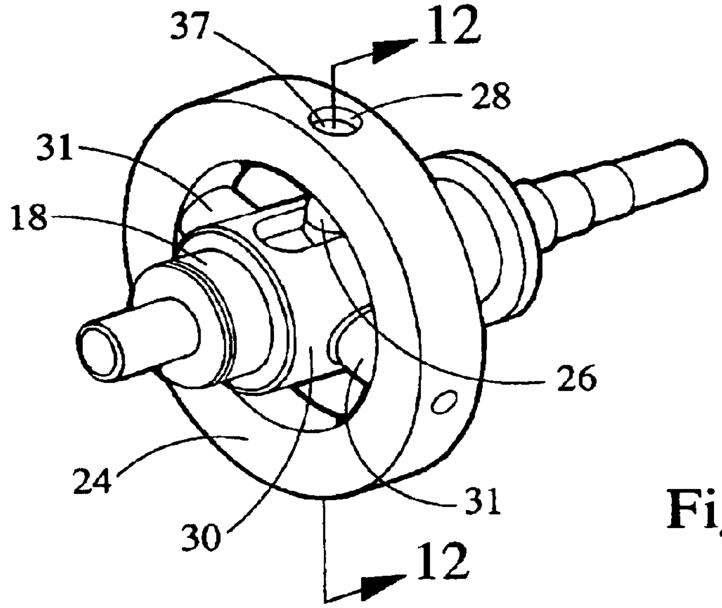

Fig. 11

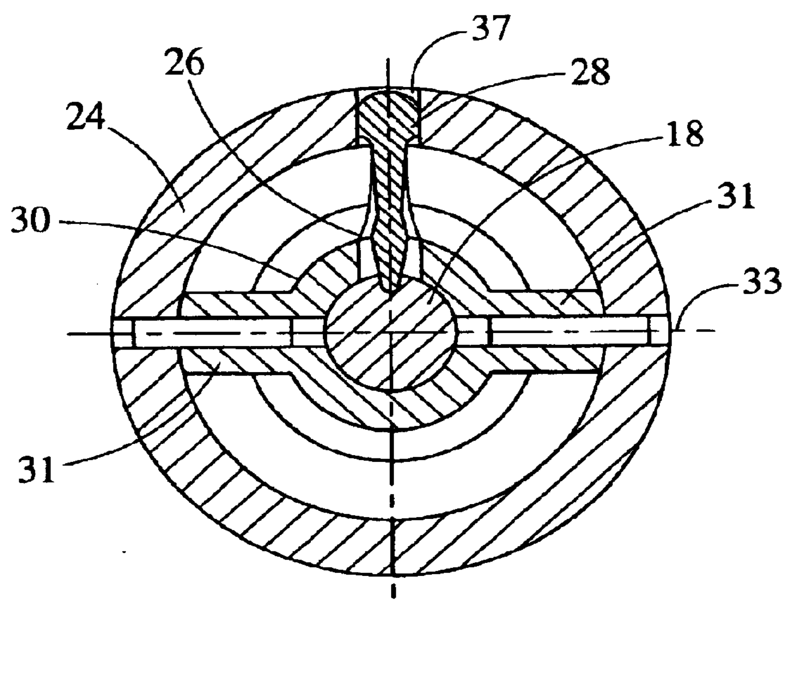

Fig. 12

VARIABLE DISPLACEMENT COMPRESSOR WITH STEPPED SHAFT

BACKGROUND OF INVENTION

1. Technical Field of the Invention

The present invention generally relates to a variable displacement compressor having a swash-ring construction. More specifically, the present invention relates to a variable displacement swash-ring compressor having a stepped shaft.

2. Description of the Prior Art

In an automotive vehicle equipped with air conditioning, a compressor is used to pump coolant through the air conditioning system to cool the vehicle. Most often, the compressor is driven by a serpentine belt of the vehicle and, hence, the speed of the compressor is controlled by the speed of the vehicle. In order to provide consistent operation of the air conditioning system, variable displacement compressors have been developed to allow the compressor to provide constant performance at all vehicle speeds. In a variable displacement compressor, higher displacement is necessary when the vehicle is idling or running at low speeds. When the vehicle is running at high speeds, the compressor is cycling much more rapidly, and therefore can provide equivalent performance at a lower displacement.

The typical automotive air conditioning compressor uses multiple pistons to pump the coolant through the system. The pistons are driven back and forth within the compressor by a plate or ring that is attached to a rotating shaft. The plate or ring is mounted at an angle relative to the shaft and engages each of the pistons. Due to the angle of the ring, radial positions around a periphery of the ring have varying axial positions within the compressor. The pistons are fixed radially within the compressor housing, so that as the shaft and ring rotate the pistons slide along the periphery of the ring and are thereby moved axially back and forth with rotations of the shaft and ring. Variable displacement is achieved by limiting the stroke of the pistons. Variable displacement compressors are available in three basic types: 1) wobble plate compressors, 2) swash-plate compressors, or 3) swash-ring compressors. The present invention is related to a swash-ring compressor.

In a swash-ring compressor, the pistons within the compressor are driven by a swash-ring. Variable displacement, by limiting the stoke of the pistons, is achieved by varying the angle of the swash-ring relative to the rotating shaft. U.S. Pat. No. 6,164,252 describes the construction of a variable displacement swash-ring compressor and is hereby incorporated by reference into the present application.

In the '252 patent, a sleeve is slidably mounted for limited axial movement along the compressor's shaft and a swash-ring is pivotally mounted onto the sleeve. A pin, rigidly mounted within and extending from the shaft, engages the swash-ring at an axial distance from the pivotal connection between the swash-ring and the sleeve. As the sleeve slides along the shaft, the swash-ring moves axially with the sleeve at the pivotal connection, but cannot move axially at the point where the pin engages the swash-ring. This causes the swash-ring to pivot about the point where the pin engages the swash-ring, thereby changing the angle of the swash-ring relative to the shaft.

As a result of the pin transferring rotation to the swash-ring, the pin undergoes very high stresses that require the diameter of the shaft to be large enough to provide sufficient strength to support the pin. Specifically, the shaft is provided

with a constant diameter over the entire length along which the sleeve slides. This makes the shaft very heavy and forces other components within the compressor to be designed around the large diameter of the shaft.

As seen from the above, there is a need to improve the design of a shaft for a compressor so that the compressor can be made lighter and more compact.

It is therefore an object of the present invention to provide an improved variable displacement compressor of lighter weight and more compact construction.

A further object of the present invention is to provide a variable displacement compressor having a stepped shaft which will reduce the size and weight of the shaft, as well as allowing other compressor components to be designed smaller and lighter.

SUMMARY OF THE INVENTION

The disadvantages of the prior art are overcome by providing a variable displacement swash-ring compressor with a stepped shaft. Use of the stepped shaft reduces the size and weight of the shaft, and therefore the compressor itself, as well as allowing other compressor components to be designed smaller and lighter.

In one aspect, the present invention is a compressor that includes a shaft rotatably mounted within the compressor. A sleeve is slidably supported on the shaft and includes collar portions, at opposite ends thereof, that support the sleeve on the shaft. A swash-ring is pivotally mounted onto the sleeve such that the swash-ring is angularly adjustable with respect to the shaft. A pin is fixedly mounted to and extends from the shaft and a distal end of the pin pivotally engages the swash-ring. The connection between the swash-ring and the pin forces the swash-ring to rotate with the shaft, while allowing the swash-ring to be angularly adjusted relative to the shaft.

The shaft includes a step adjacent the pin, defining a reduced diameter portion on the shaft and end thereof. By way of this step and reduced diameter portion, an annular gap is formed between the shaft and the inner diameter of the sleeve where the sleeve overlies the reduced diameter portion of the shaft. The annular gap therefore extends along a portion of the sleeve between the first and second collar portions. The sleeve is further biased along the shaft by a spring whose position may be varied.

In another aspect of the present invention, the shaft includes a pair of steps, with each of the steps being located on opposing sides of the pin.

Further variations on the invention include various locations for the spring and for a positive stop for the sleeve. The positive stop can be defined by the step within the shaft, or, the shaft may include a snap ring groove with a snap ring engaged therein to define a positive stop for the sleeve.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a sectional view of a prior art swash-ring compressor;

FIG. **2** is a perspective view of the shaft, swash-ring and sleeve of the compressor of FIG. **1**;

FIG. **3** is a sectional view of a first preferred embodiment of the present invention wherein the shaft includes a single step;

FIG. **4** is a sectional view of a variation of the first preferred embodiment seen in FIG. **3**, wherein a spring is positioned within a gap formed between the sleeve and the shaft adjacent the step;

FIG. **5** is a sectional view of another preferred embodiment including a single step;

FIG. **6** is a sectional view of a variation of the preferred embodiment seen in FIG. **5** wherein a spring is positioned within a gap formed adjacent the step, between the sleeve and the shaft;

FIG. **7** is a sectional view of yet another preferred embodiment of the present invention wherein the shaft includes a pair of steps;

FIG. **8** is a sectional view of a variation of the preferred embodiment seen in FIG. **7** wherein a spring is positioned within a gap formed adjacent the step between the sleeve and the shaft, and the shaft includes a snap ring and a spring washer to provide a positive stop for the sleeve;

FIG. **9** is a sectional view of another variation, similar to FIG. **8**, wherein a spring is positioned within a gap formed adjacent the step, between the sleeve and the shaft and a positive stop is defined by one of the steps;

FIG. **10** is a sectional view of a preferred embodiment having a shortened shafts;

FIG. **11** is a perspective view of a shaft and swash-ring of the present invention; and

FIG. **12** is a sectional view taken along line **12**—**12** of FIG. **11**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. **1** and **2**, a prior art variable displacement piston compressor is shown therein and generally designated at **10**. The variable displacement compressor **10** is a swash-ring type compressor having a rotating driven shaft **12** with a swash-ring **14** supported thereon. A sleeve **15** is slidable along the shaft **12** and is pivotally connected to the swash-ring **14**. By sliding the sleeve **15** along the shaft **12**, the angle of the swash-ring **14** is varied. A complete description of the variable displacement swash-ring compressor is found in U.S. Pat. No. 6,164,252 which has been incorporated by reference into the present application.

Referring now to FIG. **3**, a variable displacement piston compressor of the present invention is shown generally at **16**. Just as the compressor **10** shown in FIG. **1**, the compressor **16** of the present invention includes a driven shaft **18** having a first end **20** and a second end **22**. The first and second ends **20**, **22** of the shaft **18** are supported within a compressor housing **21** by bearing elements **23**. The shaft **18** is adapted for rotational movement within the compressor housing **21**. Typically, the shaft **18** will have a pulley (not shown) mounted to one of the ends **20**, **22**. The pulley engages a serpentine belt of an automotive vehicle, although, the concepts of the present invention would work on a compressor where the shaft **18** is driven by other means.

A sleeve **30** is slidably supported on the shaft **18** and includes a first collar portion **32** and a second collar portion **34** at opposing ends thereof. The first and second collar portions **32**, **34** support the sleeve on the shaft **18**. The shaft **18** further includes a stepped profile defining a reduced diameter portion **35**. Where the sleeve **30** overlies the reduced diameter portion **35**, an annular gap **38** is formed between an inner diameter of the sleeve **30** and the shaft **18**. A spring **36** is mounted on the shaft **18** to bias the sleeve **30** along the shaft **18** for adjustment purposes of a swash-ring **24** further discussed below. The spring **36** can be positioned between one of the collar portions **32**, **34** of the sleeve **30** and a structural portion of the compressor **16**, or the spring **36** can be positioned within the gap **38**.

The swash-ring **24** is pivotally mounted onto the sleeve **30**. The swash-ring **24** is supported on the sleeve **30** by a pair of bearing pins **31**. The bearing pins **31** are axially aligned with one another and extend radially outward from diametrically opposed sides of the sleeve **30**. The bearing pins **31** pivotally engage the swash-ring **24** wherein the swash-ring **24** is pivotable about an axis **33** running longitudinally through the bearing pins **31** and through the shaft **18**. The pivotal connection between the swash-ring **24** and the sleeve **30** allows the angle of the swash-ring **24** relative to the shaft **18** to be adjusted.

A pin **26** is mounted within and extends from the shaft **18**. The swash-ring includes a radially inwardly open pocket **37**. A distal end **28** of the pin **26** pivotally engages the radially inwardly open pocket **37** such that the swash-ring **24** is allowed to pivot about the distal end **28** of the pin **26**. However, the connection between the distal end **28** of the pin **26** and the swash-ring **24** forces the swash-ring **24** to rotate with the shaft **18**.

In one embodiment, the shaft **18** includes a step **40** adjacent to the pin **26** and toward one of the first and second ends **20**, **22** of the shaft **18**. The step **40** formed within the shaft **18** allows the diameter of the shaft **18** to remain large enough at and near the pin **26** to provide sufficient strength to support the pin **26**. The diameter of portions **35** of the shaft **18** not immediately adjacent the pin **26** is reduced, thereby reducing the weight of the shaft **18** and allowing other components, which are designed around the shaft **18**, to be made smaller. The advantages of the present invention include lightening the compressor **16** as well as allowing a reduction of the overall size of the compressor **16**.

In the first preferred embodiment, seen in FIG. **3**, the shaft **18** includes a single step **40** that is adjacent the pin **26** toward the first end **20** of the shaft **18**. A spring **36** is positioned about the shaft **18** between the sleeve **30** and a structural component **41** of the compressor **16**. Preferably, the shaft **18** includes a stop **42** to provide a positive stop for the sleeve **30**. For the stop **42**, the shaft **18** can include a snap ring groove **44** having a snap ring **46** disposed therein defining the stop **42**. The stop **42** can be defined by the step **40** within the shaft **18**. Alternatively, in either case, a spring washer **48** is positioned against the stop **42** to buffer contact between the sleeve **30** and the stop **42**.

In FIG. **3**, the snap ring **46** mounted onto the shaft **18** toward the second end **22** of the shaft **18** defines the stop **42**. Additionally, the first collar portion **32** of the sleeve **30** is larger than the second collar portion **34** of the sleeve **30** due to the smaller diameter of the shaft **18** toward the first end **20**. This allows the sleeve **30** to slide evenly along the shaft **18** with the step **40** located between the first and second collar portions **32**, **34**. Referring to FIG. **4**, the spring **36** is seen located in an alternate position, within the gap **38** between the first collar portion **32** and the step **40**.

A second preferred embodiment includes a single step **40** which is adjacent the pin **26** and toward the second end **22** of the shaft **18**. Referring to FIG. **5**, the spring **36** is positioned between the sleeve **30** and a structural component **41** of the compressor **16** and the stop **42** is provided by a snap ring **46** mounted to the shaft **18** in the reduced diameter portion **35** of the shaft **18**. In this construction, the second collar portion **34** of the sleeve **30** is larger than the first collar portion **32** of the sleeve **30** due to the smaller diameter of the shaft **18** toward the second end **20**. This allows the sleeve **30** to slide evenly along the shaft **18** with the step **40** located between the first and second collar portions **32**, **34**.

As seen in FIG. **6**, the spring **36** is alternatively mounted within the gap **38** between the second collar portion **34** of the sleeve **30** and the step **40**.

In another embodiment, the shaft **18** can include a pair of steps **40***a*, **40***b* with one of the steps **40***a*, **40***b* being positioned adjacent the pin **26** and toward each of the first and second ends **20**, **22** of the shaft **18**. An embodiment of this variety is shown in FIG. **7**. The spring **36** is positioned between the sleeve **30** and a structural component **41** of the compressor **16**, just as the first preferred embodiment shown in FIG. **3**. The stop **42** of this embodiment, however, is defined by the step **40***a* within the shaft **18** and the spring washer **48** rests against the face of the step **40***a*. The length of sleeve **30** is formed such that the second collar portion **34** of the sleeve **30** will not extend beyond the step **40***b* when the sleeve **30** moved. As in prior embodiments first collar portion **32** is larger than the second collar portion **34**.

In a first variation of the embodiment seen in FIG. **7**, the second collar portion **34** does extend beyond the step **40***b*, therefore the second collar portion **34** also has a size to allow the sleeve **30** to slide along the smaller diameter shaft **18**, as shown in FIG. **8**. The spring **36** in this variation is placed within the gap **38** between the step **40***b* and the second collar portion **34**. The stop **42** is defined by a snap ring **46** with a spring washer **48** adjacent thereto. The stop **42** could also be defined by the step **40***a* toward the first end **20** as shown in FIG. **9**.

FIG. **10** illustrates a further embodiment wherein the bearings **50** which support the shaft **18** within the compressor **16** are moved toward the pin **26** such that the overall length of the shaft **18** can be reduced. This configuration having a shortened shaft **18** could be utilized with any of the previously discussed preferred embodiments.

The foregoing discussion discloses and describes three preferred embodiments, and variations thereof, of the present invention. One skilled in the art will readily recognize from such discussion, and from the accompanying drawings and claims, that changes and modifications can be made to the invention without departing from the true spirit and fair scope of the invention as defined in the following claims. The invention has been described in an illustrative manner, and it is to be understood that the terminology which has been used is intended to be in the nature of words of description rather than of limitation.

What is claimed is:

1. A variable displacement compressor comprising;

a housing;

a shaft supported within said housing for rotational movement about an axis running longitudinally therethrough, said shaft including a step defining a reduced diameter portion along said shaft;

a pin extending generally outward from said shaft and including a distal end, said step being formed within said shaft adjacent said pin;

a sleeve mounted about said shaft, said sleeve being slidable along said shaft and rotatable with said shaft, said sleeve extending over said step and defining a radial gap between said sleeve and said reduced diameter portion of said shaft;

a swash-ring pivotally supported on said sleeve by a pair of bearing pins, said bearing pins being axially aligned with one another and extending radially outward from diametrically opposed sides of said sleeve and pivotally engaging said swash-ring wherein said swash-ring is pivotable about an axis running longitudinally through said bearing pins and through said shaft, said swash-ring being rotatable with said shaft and further including a radially inwardly open pocket, said distal end of said pin being pivotally received within said pocket, said swash-ring further defining an angle with respect to said longitudinal axis of said shaft, said angle being adjustable with respect to said axis;

a piston supported within said housing, said piston coupled to said swash-ring whereby rotation of said swash-ring causes reciprocating axial movement of said piston; and

a biasing member engaging said sleeve and biasing said sleeve along said shaft.

2. The variable displacement compressor of claim **1** wherein said biasing member is positioned between said sleeve and a structural portion of said compressor.

3. The variable displacement compressor of claim **1** wherein said biasing member is positioned within said gap.

4. The variable displacement compressor of claim **1** wherein said biasing member is a spring.

5. The variable displacement compressor of claim **2** wherein said shaft includes a pair of steps, one of said steps being located adjacent said pin toward each of a first end and a second end of said shaft.

6. The variable displacement compressor of claim **4** wherein said shaft includes a stop to provide a positive stop for said sleeve.

7. The variable displacement compressor of claim **6** wherein said stop is defined by said step.

8. The variable displacement compressor of claim **6** wherein said shaft includes a groove, said stop being defined by a snap ring engaged within said groove.

9. The variable displacement compressor of claim **6** further including a spring washer positioned against said stop.

10. A variable displacement compressor comprising;

a housing;

a shaft supported within said housing for rotational movement about an axis, said shaft including a pair of steps defining a reduced diameter portion along said shaft;

a pin extending generally outward from said shaft and including a distal end, one of said steps being formed within said shaft adjacent said pin on each side of said pin;

a sleeve mounted about said shaft, said sleeve being slidable along said shaft and rotatable with said shaft, said sleeve extending over at least one of said steps and defining a radial gap between said sleeve and said reduced diameter portion of said shaft;

a swash-ring pivotally supported on said sleeve by a pair of bearing pins, said bearing pins being axially aligned with one another and extending radially outward from diametrically opposed sides of said sleeve and pivotally engaging said swash-ring wherein said swash-ring is pivotable about an axis running longitudinally through said bearing pins and through said shaft, said swash-ring being rotatable with said shaft and further including a radially inwardly open pocket, said distal end of said pin being pivotally received within said pocket, said swash-ring further defining an angle with said longitudinal axis of said shaft, said angle being adjustable with respect to said axis;

a piston supported within said housing, said piston being coupled to said swash-ring whereby rotation of said swash-ring causes reciprocating axial movement of said piston; and

a biasing member engaging said sleeve and biasing said sleeve along said shaft.

11. The variable displacement compressor of claim **10** wherein said biasing member is positioned between said sleeve and a structural portion of said compressor.

12. The variable displacement compressor of claim **10** wherein said biasing member is positioned within said gap.

13. The variable displacement compressor of claim **10** wherein said steps are located adjacent each side of said pin toward each end of said shaft.

14. The variable displacement compressor of claim **10** wherein said shaft includes a stop to provide a positive stop for said sleeve.

15. The variable displacement compressor of claim **14** wherein said stop is defined by said step.

16. The variable displacement compressor of claim **14** wherein said shaft includes a groove, said stop being defined by a snap ring engaged within said groove.

17. The variable displacement compressor of claim **14** further including a spring washer positioned against said stop.

* * * * *