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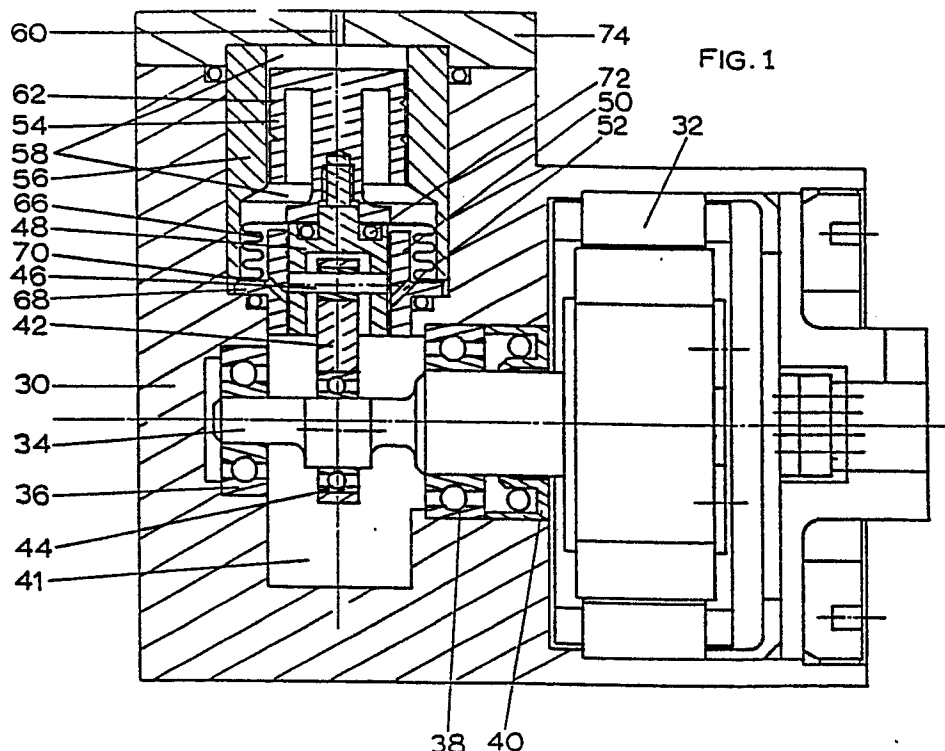
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⑤④ **Rotary compressors.**

⑤⑦ A rotary compressor comprising a rotary power source, a crankshaft (34) driven by the rotary power source, a piston (54) formed with a dynamic clearance seal and a bellows (66) for sealing the working volume (58) surrounding the piston (54) from the volume (41) surrounding the crankshaft (34).



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FIELD OF THE INVENTION

The present invention relates to compressors generally and more particularly to rotary compressors.

BACKGROUND OF THE INVENTION

One of the major factors limiting the operating lifetime of cryocoolers and other devices employing rotary compressors are contamination of the working gas volume by lubricants and other debris. For example, conventional Stirling cycle cryocoolers have a measured reliability of 300 hours MTBF. Four major failure modes have been identified in these cryocoolers: rotary bearing failure, compressor piston seal failure, contamination of the working gas volume by debris and lubricants and helium leakage.

Normally a dynamic seal of Teflon-like plastic is employed in conventional cryocoolers. The use of such seal continuously introduces debris into the cryocooler, hastening total breakdown of the system due to blockage of the heat exchanger. The use of a dynamic seal also contributes to breakdown in another way. In the final stages of seal breakdown, at the 200 - 300 hours stage of operation, the dynamic seal becomes thin and thus improves the seal. This causes a large increase in pressure wave amplitude, causing failure of bearings and other components under excessive loading.

Cryogenic refrigerators including clearance seals are known in the art, as exemplified by U.S. Patents 4,539,818 and 4,520,629. U.S. Patent 4,539,818 employs a ceramic clearance seal which, due to its low thermal conductivity, would appear to be unsuitable for use with a rotary drive compressor in which friction at the seal is significant. U.S. Patent 4,520,629 employs a piston guide, which is relatively complex and space-consuming.

SUMMARY OF THE INVENTION

The present invention seeks to provide an improved rotary compressor which will have an MTBF of up to 4,000 - 5,000 hours.

There is thus provided in accordance with a preferred embodiment of the present invention, a rotary compressor comprising a rotary power source, a crankshaft driven by the rotary power source, a piston formed with a dynamic clearance seal and apparatus for sealing the working volume surrounding the piston from the volume surrounding the crankshaft.

Further in accordance with a preferred embodiment of the invention, the dynamic clearance seal comprises a labyrinth seal.

According to an alternative embodiment of the invention, the dynamic clearance seal comprises a metal/metal clearance seal.

Additionally in accordance with an embodiment of the invention, the apparatus for sealing comprises a bellows.

The apparatus of the present invention overcomes three of the four failure modes identified above in connection with conventional Stirling cryocoolers, rotary bearing failure, compressor piston seal failure and contamination of the working gas volume by debris and lubricants.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description taken in conjunction with the drawings in which:

Fig. 1 is a sectional illustration of a compressor constructed and operative in accordance with a preferred embodiment of the present invention; and

Fig. 2 is a sectional illustration of a portion of a compressor constructed and operative in accordance with an alternative embodiment of the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Reference is now made to Fig. 1 which illustrates a compressor constructed and operative in accordance with a preferred embodiment of the present invention and comprising a housing 30 in which is disposed an electric motor 32 having an eccentric output crankshaft 34. Crankshaft 34 is supported in housing 30 by means of bearings 36 and 38. A static seal 40 seals the electric motor 32 from the volume 41 surrounding the crankshaft.

A connecting rod 42 is bearing mounted at one end onto crankshaft 34 by means of a bearing 44 and onto a wrist pin 46 which is mounted onto a first piston portion 48. First piston portion 48 is slidably mounted in a cylindrical mounting sleeve 50 which is formed with an air relief channel 52.

First piston portion is fixedly coupled to a second piston portion 54 which is slidably and sealingly disposed within a cylindrical channel 56 defining a second piston portion working volume 58. Volume 58 may communicate with a regenerator

and heat exchanger (not shown) of a Stirling cryocooler or any other suitable compressor output device via an output channel 60.

It is a particular feature of the present invention that second piston portion 54 is formed with a dynamic clearance seal 62, such as a labyrinth seal or a metal/metal clearance seal typically formed of stainless steel. The use of this seal prevents contamination of the working volume 58 and thus of the regenerator of a cryocooler connected therewith or of any other compressor output device by particulate matter which would normally be rubbed off the seal when other types of seals are used.

It is also a particular feature of the present invention that the second piston portion working volume 58 is sealed from the remainder of the interior of the compressor, i.e. from volume 41, in order to prevent contamination of the working volume 58. This sealing is effected, in a preferred embodiment of the invention by means of a bellows 66, which is sealed at one end between a flange 68 integrally formed with mounting sleeve 50 and a butt end 70 of channel 56. The opposite end of bellows 66 is sealed between the first piston portion 48 and the second piston portion 54 by means of a sealing ring 72. The bellows 66 is typically formed of stainless steel.

It is a particular feature of the present invention that the bellows 66 is compressed by a maximum amount which is a very small percentage of its overall length, typically under 10%.

It is also a particular feature of the present invention that the pressures on opposite sides of the bellows are maintained generally the same, thus preventing premature bellows failure. This is made possible by location of the bellows upstream of the working gas volume 58, so that the pressure pulses generated by the compressor are not applied thereto.

An end plate 74 is typically sealed onto the remainder of housing 30 by means of a sealing ring 76.

Reference is now made to Fig. 2, which illustrates a compressor similar in all relevant respects to the compressor of Fig. 1, with the exception of the structural features described hereinbelow. Similar structural components are identified by the same reference numerals in Figs. 1 and 2.

In the embodiment of Fig. 2, piston portions 148 and 154 are typically integrally formed. In this embodiment bellows 166 is sealingly mounted at one end thereof onto a shoulder 168 of the first piston portion 148 and sealingly mounted at an opposite end thereof onto a cylindrical protrusion 170 of cylindrical channel 56.

It will be appreciated by persons skilled in the

art that the present invention is not limited by what has been particularly shown and described hereinabove. Rather the scope of the present invention is defined only by the claims which follow:

Claims

1. A rotary compressor comprising a rotary power source, a crankshaft driven by said rotary power source, a piston formed with a dynamic clearance seal and apparatus for sealing a working volume surrounding said piston from a volume surrounding said crankshaft.

2. Apparatus according to claim 1 and wherein said dynamic clearance seal comprises a labyrinth seal.

3. Apparatus according to claim 1 and wherein said dynamic clearance seal comprises a metal/metal clearance seal.

4. Apparatus according to claim 2 and wherein said dynamic clearance seal comprises a metal/metal clearance seal.

5. Apparatus according to claim 1 and wherein said apparatus for sealing comprises a bellows.

6. Apparatus according to claim 2 and wherein said apparatus for sealing comprises a bellows.

7. Apparatus according to claim 3 and wherein said apparatus for sealing comprises a bellows.

8. Apparatus according to claim 5 and wherein said bellows is formed of stainless steel.

9. Apparatus according to claim 6 and wherein said bellows is formed of stainless steel.

10. Apparatus according to claim 7 and wherein said bellows is formed of stainless steel.

11. Apparatus according to claim 5 and wherein said bellows has a compressive travel equal to less than 10% of its length along a travel axis.

12. Apparatus according to claim 6 and wherein said bellows has a compressive travel equal to less than 10% of its length along a travel axis.

13. Apparatus according to claim 7 and wherein said bellows has a compressive travel equal to less than 10% of its length along a travel axis.

14. Apparatus according to claim 8 and wherein said bellows has a compressive travel equal to less than 10% of its length along a travel axis.

15. Apparatus according to claim 9 and wherein said bellows has a compressive travel equal to less than 10% of its length along a travel axis.

16. Apparatus according to claim 10 and wherein said bellows has a compressive travel equal to less than 10% of its length along a travel axis.

17. Apparatus according to claim 5 and wherein said bellows is arranged such that the pressure at both sides thereof is generally equal. 5

18. Apparatus according to claim 6 and wherein said bellows is arranged such that the pressure at both sides thereof is generally equal. 10

19. Apparatus according to claim 7 and wherein said bellows is arranged such that the pressure at both sides thereof is generally equal.

20. Apparatus according to claim 8 and wherein said bellows is arranged such that the pressure at both sides thereof is generally equal. 15

21. Apparatus according to claim 9 and wherein said bellows is arranged such that the pressure at both sides thereof is generally equal.

22. Apparatus according to claim 10 and wherein said bellows is arranged such that the pressure at both sides thereof is generally equal. 20

23. Apparatus according to claim 11 and wherein said bellows is arranged such that the pressure at both sides thereof is generally equal. 25

24. Apparatus according to claim 12 and wherein said bellows is arranged such that the pressure at both sides thereof is generally equal.

25. Apparatus according to claim 13 and wherein said bellows is arranged such that the pressure at both sides thereof is generally equal. 30

26. Apparatus according to claim 14 and wherein said bellows is arranged such that the pressure at both sides thereof is generally equal.

27. Apparatus according to claim 15 and wherein said bellows is arranged such that the pressure at both sides thereof is generally equal. 35

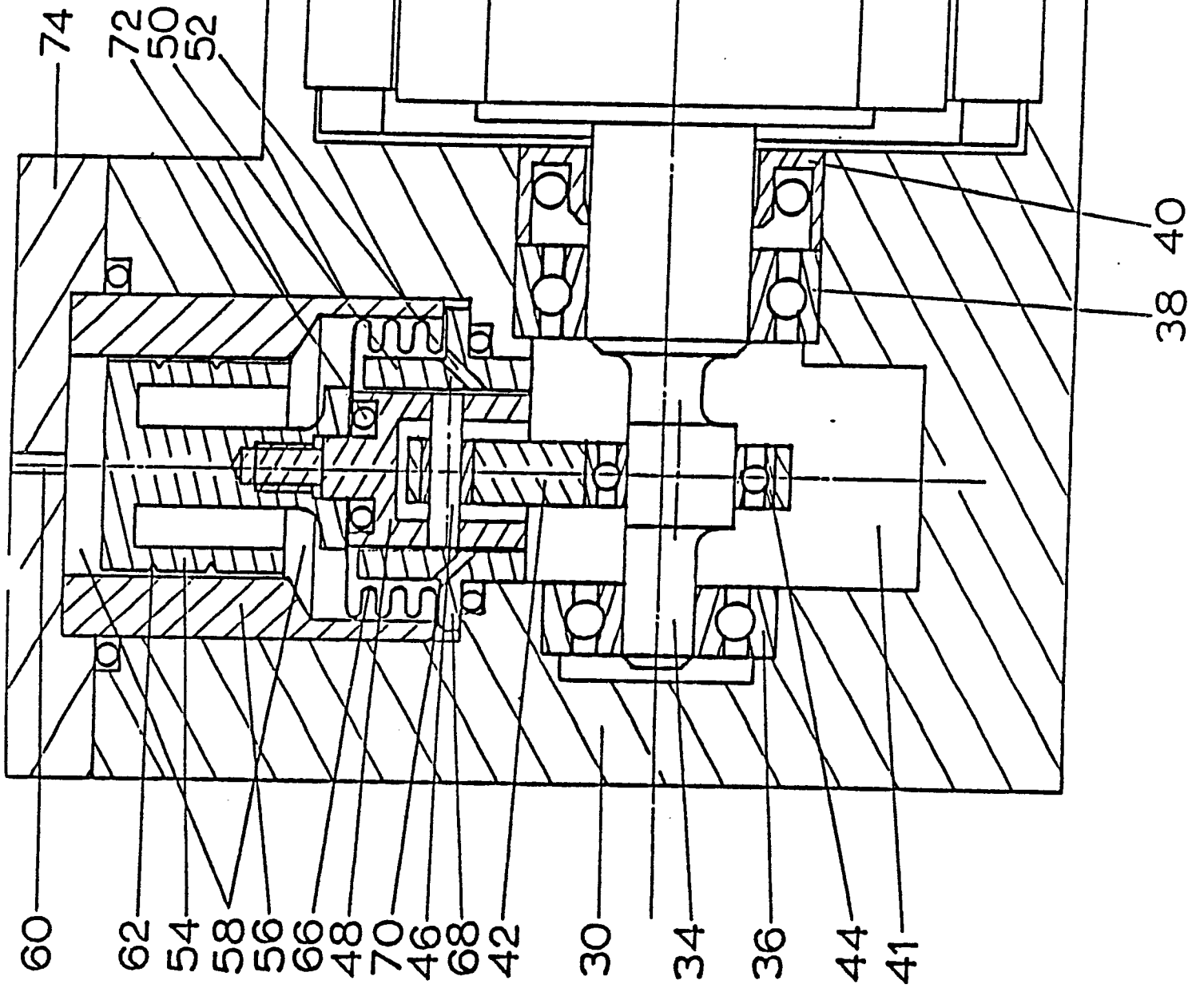
28. Apparatus according to claim 16 and wherein said bellows is arranged such that the pressure at both sides thereof is generally equal. 40

45

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FIG. 1



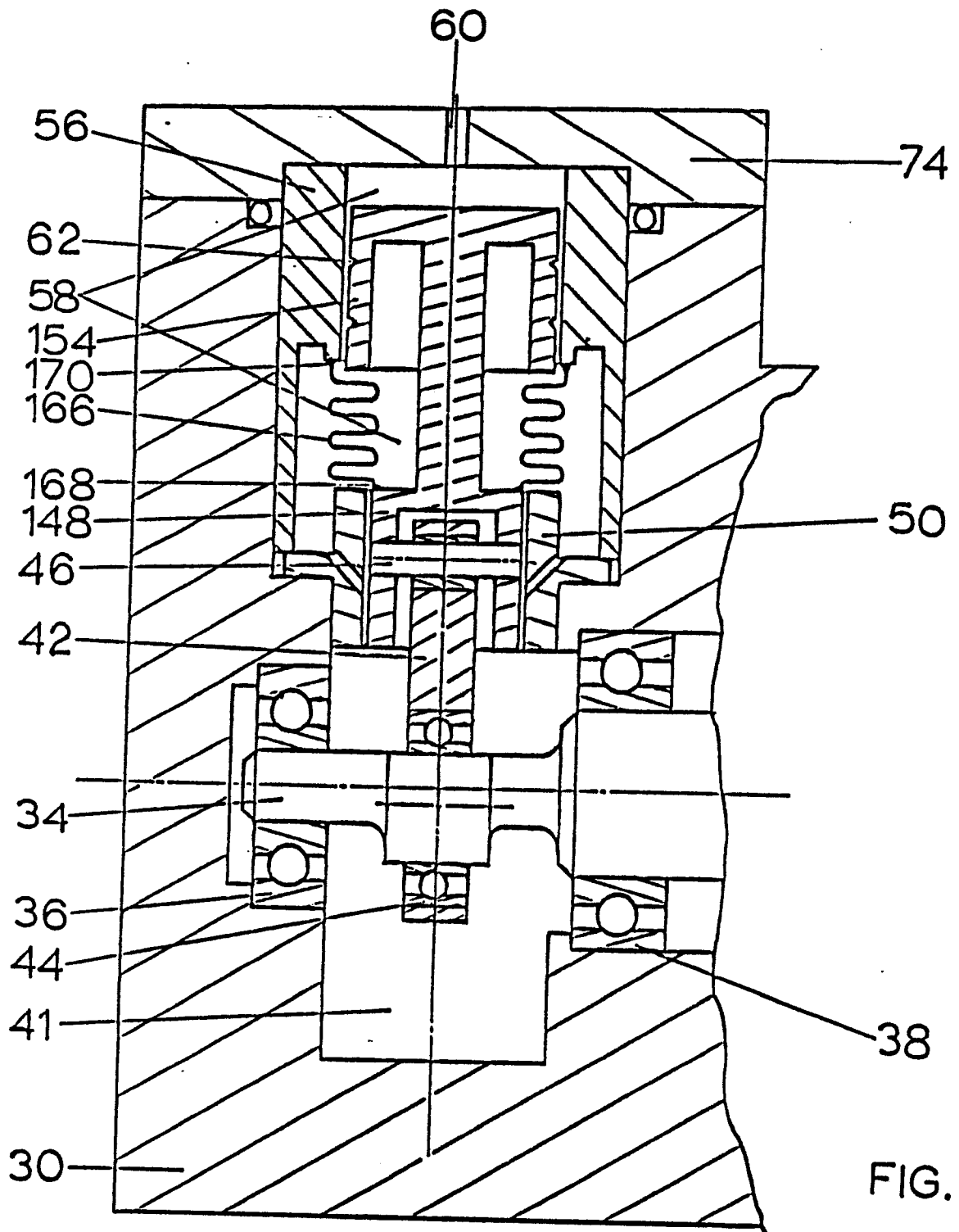


FIG. 2