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(54) Compressors for refrigeration apparatus.

(57) A piston (42) is integral with a housing (40, 43) of the compressor and a cylinder (24) is mounted within the housing (40, 43) by means of radially stiff, axially flexible resilient elements (19, 20). An electromagnetic linear motor (10, 11, 14) for effecting reciprocating movement of the cylinder (24) has a stationary element (11) secured to the housing (40, 43) and radially outer and inner portions of the resilient elements (19, 20) are secured directly to the stationary element (11) and the cylinder (24). Preferably the resilient elements lie in planes transverse to the axes of the piston (42) and cylinder (24), and cooperating portions of the piston (42) and cylinder (24) lie entirely within a zone between those planes.

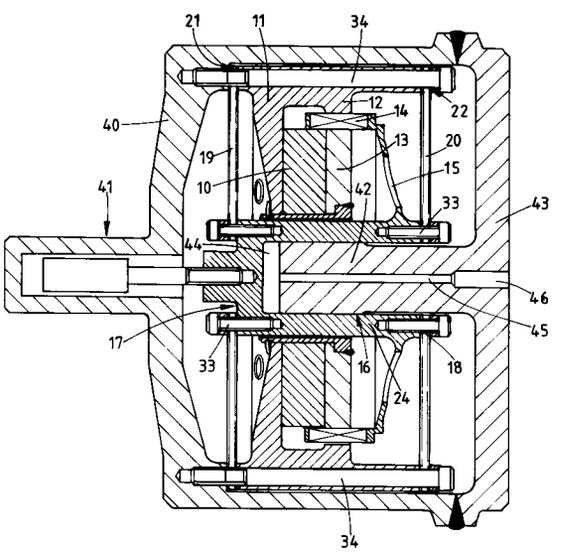

FIG. 1.

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This invention relates to compressors for refrigeration apparatus, and in particular to compressors for cryogenic refrigerators. Refrigerator compressors are typically piston and cylinder devices and in compressors for small refrigerators it is known to cause reciprocation between the piston and cylinder by means of a linear motor.

The piston and cylinder require to have a very small running clearance, and this requirement is particularly true of cryogenic refrigerators in which the working fluid is commonly helium. In published PCT application WO 89/03480 a seal between the piston and cylinder is provided by ceramic surfaces on these parts, and the cylinder forms part of a moving armature which is supported on the piston. The rubbing surfaces are therefore subject to wear and increased clearance, and consequent leakage of refrigerant fluid.

It has been proposed in, for example, GB-A 2062773, that the piston shall be of a hard material and that the cylinder shall have a relatively soft antifriction lining such as PTFE. In this latter reference the piston is supported within the cylinder so as theoretically to remain concentric therewith. However, with such a construction it has been found in practice that even if assembly of the piston, cylinder and linear motor is performed carefully on jigs, final tightening of threaded elements used to secure the components can cause sufficent distortion to produce unacceptable misalignment between the piston and cylinder. The probability of such misalignment increases with the number of components which are required to be assembled. Even a very small misalignment between the piston and cylinder can result in wear on the cylinder lining and consequent leakage of refrigerant fluid.

It is an object of the invention to provide a compressor for a refrigeration apparatus, in which wear between the piston and cylinder is substantially reduced. In particular it is an object to provide such a compressor in which the piston and cylinder are independently supported and in which misalignment between these parts as a result of initial assembly is substantially reduced.

According to the invention there is provided a compressor for a refrigeration apparatus, comprising a housing containing a piston which is integral with the housing, a cylinder and an electromagnetic linear motor for effecting reciprocating motion between the piston and cylinder, a stationary element of the motor being secured within the housing, and the cylinder being mounted in the housing by means of radially stiff, axially flexible resilient elements whose radially outer and inner portions are secured directly to the stationary element and the cylinder respectively.

An embodiment of the invention will now be described by way of example only and with reference to the accompanying drawings, in which:-

Figure 1 is a longitudinal section through a compresssor for a Stirling type cryogenic refrigerator and Figure 2 is an end view of a spring component of Figure 1.

An annular permanent magnet 10 is mounted in annular yoke 11 one end 12 of which defines a magnetic pole having a first polarity. An annular pole piece 13 is secured to the magnet and has a second polarity. The gap between the poles 12,13 is occupied by an annular coil 14 which is mounted on the periphery of a non-magnetic carrier 15. The carrier 15 extends radially from a cylinder element 24 which has a blind bore 16 and annular end faces 17,18. The carrier 15 is supported within the yoke 11 by two spring assemblies 19,20 which are radially stiff and axially flexible. The assemblies 19,20 are secured at their radially inner ends to the faces 17, 18 respectively, and at their outer ends to respective opposite end faces 21,22 of the yoke 11. The yoke 11 and carrier 15 are machined so that the distance between the end faces 17,18 is equal to that between the faces 21,22.

The assemblies 19,20 each comprise a stack of flat spiral springs 30 which are separated from each other at their peripheries and their radially inner ends by circular spacers 35. As shown in Figure 2 each spring 30 comprises a thin metal disc of resilient material, formed with slits 31 which define a multistart spiral. Twelve equi-spaced holes 32 at each of the peripheries and inner circumferences enable the discs 30 and spacers 35 to be secured together and the resulting assemblies 19,20 to be secured by bolts 33 (Fig.1) to the carrier 15, and to the yoke 11 by bolts 34. As shown in Figure 1 the bolts 34 also secure the yoke 11 to a housing part 40 in which is mounted one element of a variable displacement transducer 41. The other element of the transducer is secured to the carrier 15. It will be seen that the peripheries of the assemblies 19,20 lie closely adjacent the wall of the housing part 40.

The cylinder 24 cooperates with a piston 42 formed integrally with a further housing part 43 to define a volume 44 within which a refrigerant can be compressed. An axial passage 45 in the piston 42 communicates with the volume 44 and with an outlet 46. The housing part 40, the magnet 10, yoke 11 and pole piece 13 may be assembled concentrically with the carrier 15 using a suitable jig which has a part equivalent to the piston 42. The required high accuracy of concentric assembly is rendered more readily achievable than in the prior art by virtue of the relatively few components involved. The yoke 11 and carrier 15 are machined so that the axial distance between the faces 17,18 is as close to the distance between that of the faces 21,22 as is readily obtainable. This equality

has the effect that accumulations of tolerance on the thicknesses of the discs 33 and their spacers will not result in pre-stressing of either of the assemblies 19,20. The bolts 33,34 may therefore be tightened down without introducing any stress which will result in misalignment when the jig, or the part thereof which includes the equivalent to the piston 42, is removed. The housing part 43 may therefore be located with respect to the part 40, using the same or a further jig, to locate the piston 42 concentrically within the bore 16 with the necessary clearance. In the specific example described the housing parts 40,43 are secured together by electron beam welding.

The absence of pre-stressing of the assemblies 19,20 also has the effect that the bore 16 will remain concentric with the piston 42 during reciprocation of the former. By permitting the peripheries of the assemblies 19,20 to extend to locations closely adjacent the wall of the housing part 40, the diameters of the discs 30 are considerably increased and permit the use of substantial bolts 33,34, which provide an improved clamping load. The described construction also permits the piston 42 to have a greater axial dimension than is possible with prior art arrangements. The clearance between the piston 42 and the bore 16 may thereby be increased without increasing leakage flow through that clearance.

Claims

1. A compressor for a refrigeration apparatus, comprising a housing (40, 43), a piston (42) integral with said housing (40, 43), a cylinder (24) and an electromagnetic linear motor (10, 11, 14) for effecting reciprocating motion between said piston (42) and said cylinder (24), characterised in that a stationary element (11) of said motor (10, 11, 14) is secured within said housing (40, 43), and said cylinder (24) is mounted in said housing (40, 43) by means of radially stiff, axially flexible resilient elements (19, 20) whose radially outer and inner portions are secured directly to said stationary element (11) and said cylinder (24) respectively.

2. A compressor as claimed in claim 1 in which said outer portions of the resilient elements (19, 20) are closely adjacent a wall of said housing (40, 43).

3. A compressor as claimed in claim 1 or claim 2 which includes two axially spaced resilient elements (19, 20) which lie in planes transverse to the axes of said piston (42) and cylinder (24).

4. A compressor as claimed in claim 3 in which cooperating portions of the piston (42) and cylinder (24) lie in a zone between said planes.

5. A compressor as claimed in claim 3 or claim 4 in which said stationary element (11) has annular end faces (21, 22) to which peripheral portions of said resilient elements (19, 20) respectively are secured, and said cylinder (24) has axial end faces (17, 18) to which radially inner portions of said resilient elements (19, 20) respectively are secured.

6. A compressor as claimed in claim 5 which includes clamping means (33, 34) for urging said resilient elements (19, 20) into engagement with said annular end faces (17, 18 and 21, 22).

7. A compressor as claimed in claim 6 in which the distance between the end faces (21, 22) of said stationary element (11) is equal to the distance between the end faces (17, 18) of said cylinder (24).

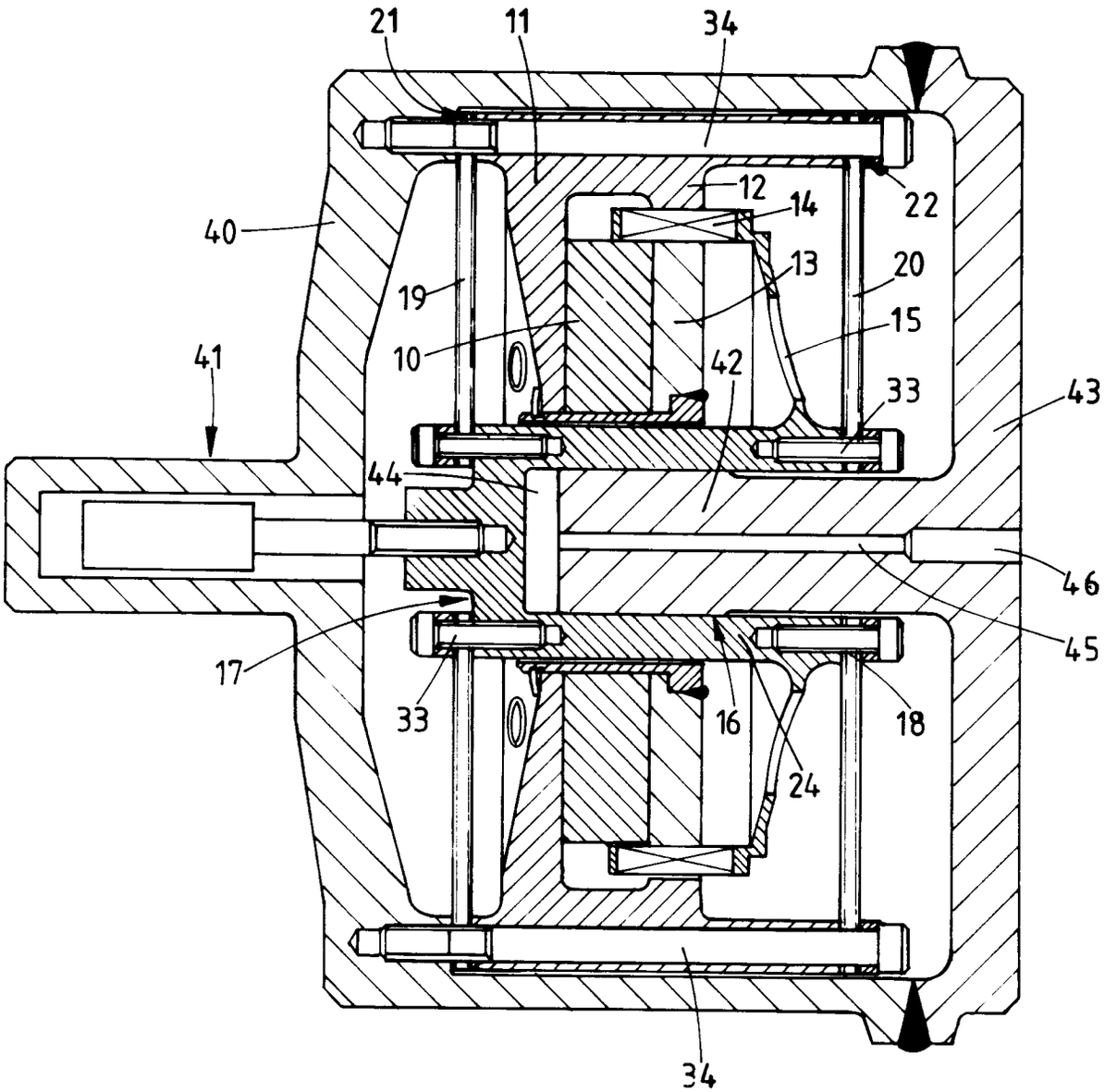
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FIG. 1.

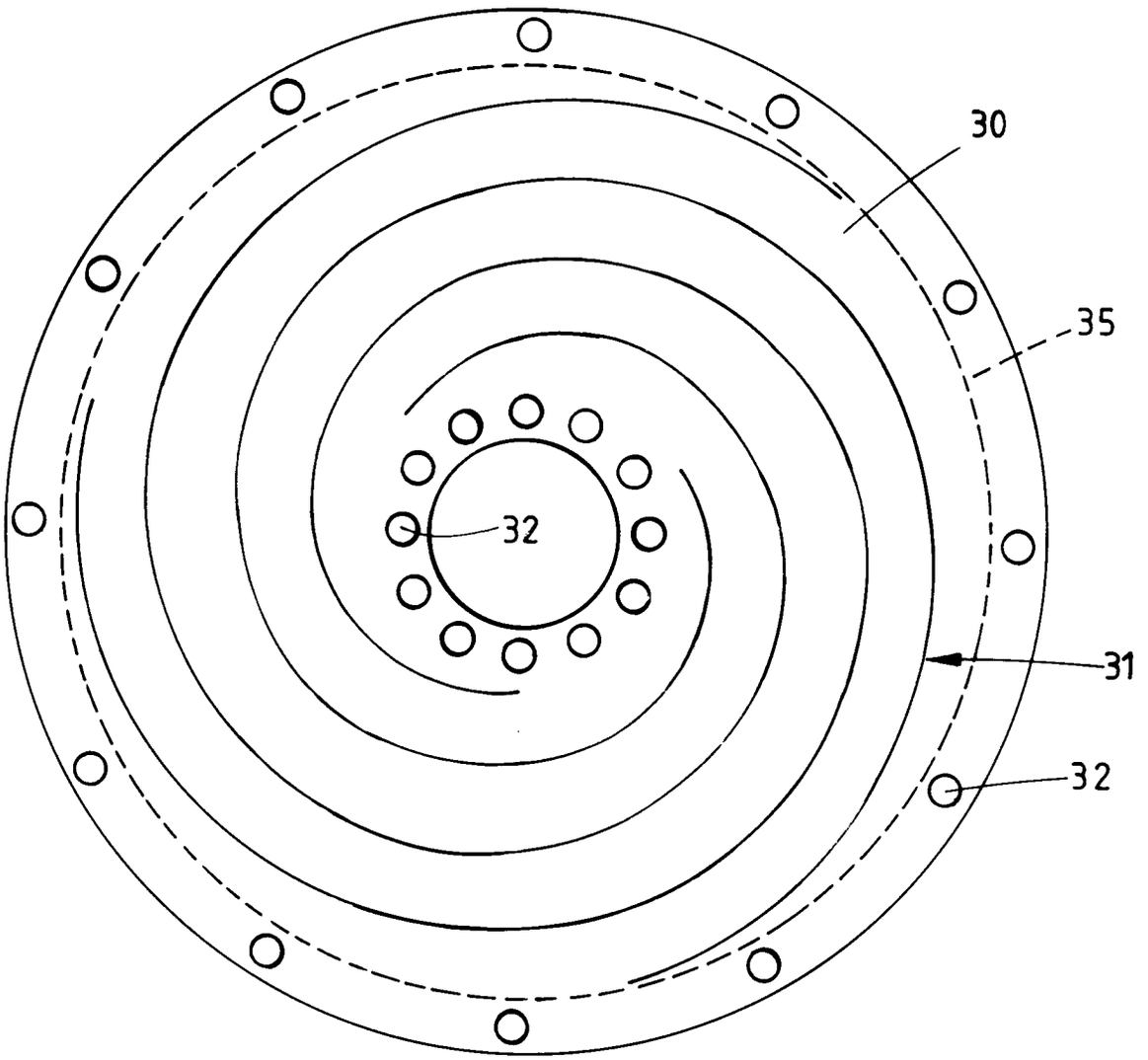

FIG.2.

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EUROPEAN SEARCH REPORT

Application Number

EP 91 30 8395

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X,P	WO-A-9 012 961 (ISIS INNOVATION) * Page 9, paragraph 2 - page 12, paragraph 1; figures 2,3 *	1-6	F 04 B 35/04
A		7	
A	WO-A-8 903 481 (HELIX TECHNOLOGY) * Page 6, line 3 - page 8, line 18; figure 1 *	1-4	
A,D	GB-A-2 062 773 (DAVEY) * Page 1, line 82 - page 2, line 22; figure 1 *	1-3,5,6	
A	FR-A-1 069 802 (ROULEMENTS A BILLES MINIATURES) * Page 1, left-hand column, lines 23-33; figure 1 *	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

F 04 B
F 25 B

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	13 December 91	BERTRAND G.

CATEGORY OF CITED DOCUMENTS

- X : particularly relevant if taken alone
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