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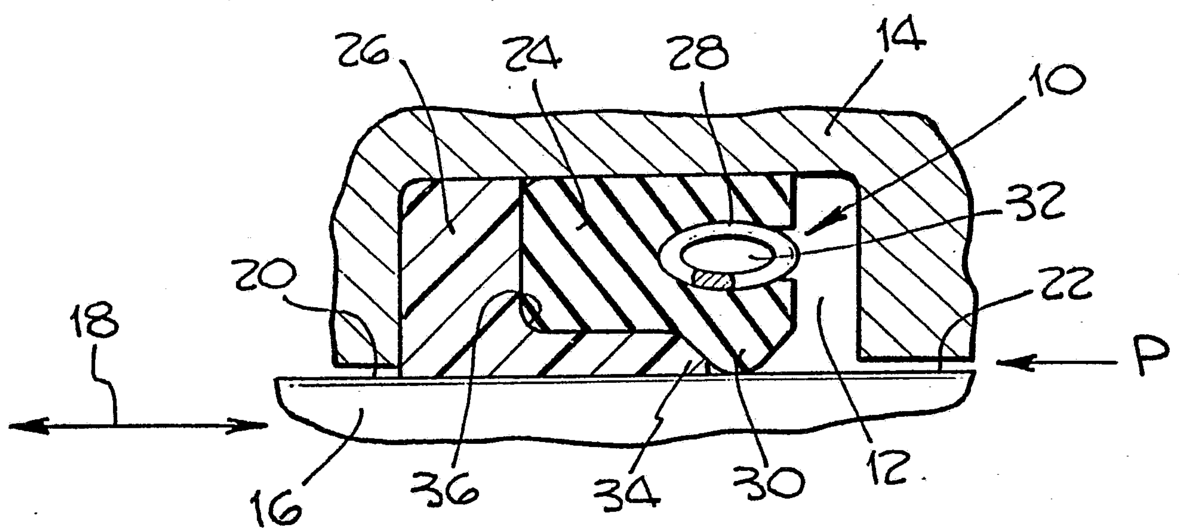
(54) Title: SPRING ENERGIZED SEAL ASSEMBLY



(57) Abstract

A multi-element seal (10) for sealing the space between two relatively reciprocating and/or rotating surfaces at both high and low pressure sealing ring (26) and an elastomeric low pressure sealing ring (24). The low temperature sealing characteristic of the assembly is improved by including a spring energizer (28) located annularly within the low pressure sealing ring (24). The spring energizer (28) is made from metal or other material which increases the sealing bias of the low pressure ring (24) against both the high pressure sealing ring (26) and the reciprocating surfaces at extremely low temperatures. As a result, leakage of fluid or gas past the seal at extremely low temperatures and low pressures is reduced.

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SPRING ENERGIZED SEAL ASSEMBLY

BACKGROUND OF THE INVENTION:

1. Field of the Invention

The present invention relates generally to multi-element seal assemblies which are used to seal the space between relatively reciprocating surfaces at both high and low pressures. More particularly, the present invention relates to a multi-element seal which is designed to maintain adequate sealing performance over a wide range of temperatures, and especially at extremely low temperatures.

2. Description of the Related Art

Multi-element seals have been used to provide a single seal assembly which is designed to provide sealing of relatively reciprocating and/or rotating surfaces at both high and low pressures. Such seals have been commonly used in a wide variety of hydraulic and fluid handling equipment where numerous annular spaces between pistons and cylinders must be sealed. These annular spaces are continually and repeatedly subjected to both high and low pressures during operation of the hydraulic equipment. The seals are commonly referred to as slipper seals.

U.S. Patent Nos. 4,231,578 and 4,268,045 disclose multi-element seals which are capable of providing adequate sealing under both high and low pressure conditions. The multi-element seals disclosed in these two patents include at least two elements. The first element is an elastomeric annular sealing ring which gives the seal low pressure sealing capability. The second element is an annular ring of non-elastomeric material such as polytetrafluorethylene which is designed to provide sealing at high pressures. An essential design feature of the seal assembly is that the elastomeric low pressure seal ring partially overlaps the high pressure seal ring. The radial displacement of the low pressure seal ring over the high pressure seal ring energizes or biases the high pressure seal ring into sealing position under high pressure conditions. This interaction between the elastomeric low pressure sealing ring and the high pressure sealing ring are essential for proper operation and sealing characteristics.

The contents of the above two referenced patents are hereby incorporated by reference.

Although the above described multi-element seals have been found to have considerable tolerance for maintaining good sealing performance over a wide temperature range, problems have been experienced at extremely low temperatures such as those experienced in outer space or arctic regions. At extremely low temperatures, the elastomeric sealing ring becomes hard and loses its ability to properly bias the second sealing ring. This hardening of the elastomer reduces the unit loading provided by both of the rings and results in leakage, especially at low pressure.

It would be desirable to provide an improved multi-element seal of the type disclosed above wherein the low temperature sealing characteristics of the assembly are improved. Such an improved seal assembly would be useful in equipment designed for extremely cold environments.

SUMMARY OF THE INVENTION:

In accordance with the present invention, a multi-element seal is provided for sealing the space between two relatively reciprocating and/or rotating surfaces at both high and low pressures and at temperatures outside the range of temperatures for which the elastomer sealing ring provides an adequate sealing bias. The present invention is based upon the discovery that a spring energizer may be located annularly within the elastomeric low pressure sealing ring to provide a sealing bias against the high pressure sealing ring and reciprocating surfaces at temperatures outside the range of temperatures at which the elastomer, by itself, provides a sufficient sealing bias. The spring energizer is metallic or is made from elastomers having the same low temperature spring characteristics.

As features of the present invention, four different metallic spring energizers may be used to provide the necessary low temperature biasing of the low pressure seal ring. As a further feature of the present invention, the metallic spring energizer is located so that it extends axially over the low pressure sealing lip and at least a portion of the high pressure sealing surface. The inclusion of spring energizers at the location specified in accordance with the present invention provides an improved multi-element seal which reduces leakage at extremely low temperatures where conventional rubber-energized seals lose their effectiveness.

As a further advantage, it was discovered that the low temperature and low pressure sealing characteristics of multi-element seals can be improved in accordance with the present invention without deleteriously affecting low and high pressure sealing characteristics of the seal assembly during normal and elevated temperature conditions.

The above described and many other features and attendant advantages of the present invention will become better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings.

DESCRIPTION OF THE DRAWINGS:

FIG. 1 is a partial sectional view of a preferred exemplary multi-element seal utilizing a slanted coil spring energizer.

FIG. 2 is a second exemplary preferred embodiment of a multi-element seal in accordance with the present invention wherein a cantilever beam spring is utilized.

FIG. 3 is a third exemplary preferred embodiment of a multi-element seal in accordance with the present invention wherein a helical spring is utilized as the metallic spring energizer.

FIG. 4 is a partial sectional view of a fourth exemplary preferred embodiment of a multi-element seal in accordance with the present invention wherein a marcel expander is utilized as the metallic spring energizer.

FIG. 5 is a side view of a portion of the slant coil spring which is utilized as the metallic spring energizer in the multi-element seal shown in FIG. 1.

FIG. 6 is a side view of a portion of the cantilever beam spring which is utilized as the metallic spring energizer in the multi-element seal shown in FIG. 2.

FIG. 7 is a side view of a portion of the helical spring which is utilized as the metallic spring energizer in the multi-element seal assembly shown in FIG. 3.

FIG. 8 is a side view of a portion of the marcel expander which is utilized as the metallic spring energizer in the multi-element seal shown in FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENT:

The multi-element seals in accordance with the present invention are designed for use at extremely low temperatures in the neighborhood of -30°F and below. The seal assemblies are designed to prevent leakage of fluids and gases from the annular space between relatively reciprocating and/or rotating surfaces. Although the seal assemblies may be used to seal a wide variety of structures, the preferred use of the seal elements is in connection with sealing hydraulic actuators which are exposed to extreme cold. Such actuators are found on hydraulic equipment which is used in the arctic regions and in outer space. Further, the multi-element seal in accordance with the present invention is intended to provide sealing against gas or fluid leakage over a pressure range varying from 0 psi up to 10,000 psi. Such fluctuations in pressure are typically found during operation of hydraulic actuators. The following description will be limited to describing preferred embodiments of the invention with respect to an annular multi-element seal which is used to seal the space between a shaft which is reciprocating and/or rotating axially with respect to a cylinder surrounding the shaft. Such a shaft-cylinder sealing arrangement is commonly found in hydraulic actuators.

A first preferred exemplary embodiment of a multi-element seal in accordance with the present invention is shown generally at 10 in FIG. 1. The seal 10 is housed within a groove 12 present in housing cylinder 14. A piston or actuator rod 16 is located within housing cylinder 14 with only the top portion of the housing cylinder and rod being shown. The rod 16 reciprocates axially relative to cylinder 14 as represented by double-headed arrow 18. The spaces 20 and 22 located at opposite ends of groove 12 are sealed by multi-element seal 10 against pressures ranging from 0 psi up to 10,000 psi, as represented by the "P" and arrow representation shown in the figures.

The multi-element seal 10 includes a low pressure sealing ring 24, a high pressure sealing ring 26 and a metallic spring energizer 28. Although the design of the low pressure sealing ring 24 as shown in FIGS. 1-4 is preferred, any of the other designs for multi-element slipper seals, such as those shown in the previously mentioned two patents, may be utilized. The low pressure seal 24 can be made from any of the conventional elastomeric materials typically used for the low pressure sealing ring in a multi-element slipper seal.

The term "slipper seal" is intended to cover those multi-element seal assemblies as disclosed in the two previously mentioned patents, as well as similar seal assemblies which are designed to provide sealing at both high and low pressures. Such slipper seals typically utilize nitrile rubber or ethylene/propylene rubber for the low pressure sealing ring. Other types of elastomers, such as thermoplastic polyurethanes, fluorocarbon elastomers, styrene/butydiene/styrene block copolymers, styrene/ethylene-butylene/styrene block copolymers, thermoplastic polyolefin elastomers, thermoplastic vulcanizates, block copolymers of polyether and polyesters, block copolymers of polyether and polyamide, as well as a variety of plastic/rubber alloys may be utilized. The basic requirement for such elastomers is that they provide sealing and biasing characteristics equivalent to nitrile rubber or ethylene/propylene rubber. All of the above elastomers are plagued with the same problem with respect to hardening at extremely low temperatures, i.e., below -30°F. At such low temperatures, these seal elements not only lose their sealing characteristics, but they also lose their ability to provide elastomeric biasing of the high pressure sealing ring into sealing contact with the surface to be sealed.

In order to overcome the above described problem at extremely low temperatures, the spring energizer 28 is located within an annular opening or groove 32 in the low pressure sealing ring 24. The spring energizer 28 in FIG. 1 is a slant coil spring. In FIG. 5, a side view of a portion of the slanted coil 28 is depicted. Slant coil springs are known for use in providing energizing or biasing of seal elements. In accordance with the present invention, the slant coil spring must be made of a metallic material which does not lose its spring biasing characteristics at extremely low temperatures. Preferably, the slant coil spring 28 will be made from stainless steel or a similarly strong and resilient metallic material.

The size of the slant coil spring, as well as the degree of slant and other spring dimensions are varied, depending upon the materials from which the low pressure sealing ring 24 and high pressure sealing ring 28 are made. Also, the intended application for the seal with respect to pressure ranges and ultimate temperature ranges must also be taken into consideration. As a result, the actual configuration of the slant coil spring 28 and its overall biasing capabilities must be determined for each application. Such a determination can be easily made experimentally with the main concern being that sufficient low temperature bias is provided to overcome the relative hardness of the elastomer material without adversely affecting the operating characteristics of the seal during operation at ambient and elevated temperatures. In addition, the size of the surfaces to be sealed must be considered in determining the degree of bias required by the slant coil spring 28 at low temperatures. The multi-element seal is designed to be used in sealing rods having diameters ranging from a fraction of an inch up to a foot or more. When larger diameter rods are being sealed, the size and biasing force exerted by the slant coil spring 28 must also be increased in order to ensure proper operation at extremely low temperatures.

The slant coil spring 28 is preferably located radially over the sealing lip 30. Further, the slant coil spring 28 should extend axially so that at least a portion of the spring 28 is located radially over the tip 34 of the high pressure sealing ring 26. The location of the slant coil spring 28 at this position was found to be advantageous in providing the desired sealing characteristics at both low temperatures and low pressure operation. Location of the metallic spring energizer at other axial points within the low pressure sealing ring 24 are not preferred.

The high pressure sealing ring 26 may be made from any of the conventional thermoplastic materials used for the high pressure sealing element in a slipper seal. Typically, polytetrafluorethylene is utilized. The polytetrafluorethylene may be substantially pure or it may be filled with a wide variety of well known fillers which are used to provide the polytetrafluorethylene with desired additional characteristics. Other high modulus materials may be used such as plastic materials typically used in the high pressure sealing rings.

One of the design feature requirements for the high pressure sealing ring 26 is that it include a seating surface 36 against which the elastomeric low pressure sealing ring 24 is biased to provide some of the unique characteristics present in slipper seals. It is this biasing of the low pressure sealing ring 24 against the high pressure sealing ring 26 which deteriorates at extremely low temperatures. The present invention is based on the discovery that the metallic spring energizers as disclosed herein are capable of replacing the lost elasticity of the low pressure sealing ring 24 at low temperatures to maintain adequate seals at extremely low temperatures without otherwise adversely affecting seal operation.

A second preferred exemplary embodiment of a multi-element seal in accordance with the present invention is shown generally at 38 in FIG. 2. The seal assembly 38 is also used to seal the spaces 20 and 22 between relatively reciprocating cylinder 14 and rod 16. The seal assembly 38 includes a low pressure sealing ring 40, high pressure sealing ring 42, and a cantilever beam spring energizer 44. A side view of a portion of the cantilever beam spring 44 is shown in FIG. 6. The cantilever beam spring is a well known spring configuration which has been used for radial biasing of seals in general. The cantilever beam spring 44 is preferably made from the same metallic materials as the slant coil spring 28. The preferred metallic material is stainless steel and related alloys. It is preferred that the cantilever spring 44 have its open end 46 facing away from the high pressure seal ring 42 to provide desired biasing of the low pressure ring 40 and high pressure ring 42. The preferred location for the cantilever beam spring 44 is also over the seal lip 48 with the closed end 50 extending over at least a portion of the high pressure sealing ring 42.

A third preferred exemplary embodiment of a multi-element seal in accordance with the present invention is shown generally at 52 in FIG. 3. The multi-element seal 52 includes a low pressure sealing ring 54, a high pressure sealing ring 56 and a metallic helical spring energizer 58. A side view of a portion of the helical spring 58 is shown in FIG. 7. The multi-element seal 52 is similar to the prior two embodiments except for the inclusion of the helical spring 58 as the metallic spring energizer. The annular opening in the low pressure seal ring 54 is modified to receive the helical spring structure. Otherwise, the seal assembly is in all major respects the same as the first preferred exemplary embodiment.

A fourth preferred exemplary embodiment of a multi-element seal in accordance with the present invention is shown generally at 60 in FIG. 4. The fourth embodiment includes a low pressure seal ring 62, a high pressure seal ring 64, and a metallic marcel expander 66 as the spring energizer. A side view of a portion of the marcel expander 66 is shown in FIG. 8. Again, the overall structure and sealing characteristics of this alternate preferred embodiment 60 is similar to the prior embodiments except for the inclusion of the marcel expander 66 as the metallic spring energizer. As was the case with the previous embodiments, the marcel expander is preferably located radially over the sealing lip 68 of the low pressure sealing ring 62 with a portion of the marcel expander 66 extending over the high pressure sealing ring 64 to provide inward bias on both sealing elements. The shape of the annular opening in the low pressure sealing ring 62 to receive the marcel expander 66 is also different from the prior spring receiving openings to the extent necessary to receive and hold the marcel expander 66.

Having thus described exemplary embodiments of the present invention, it should be noted by those skilled in the art that the within disclosures are exemplary only and that various other alternatives, adaptations and modifications may be made within the scope of the present invention. Thus, by way of example and not of limitation, the orientation of the exemplary multi-element seals can be reversed so that exterior surface sealing can be provided as opposed to the interior surface sealing shown in the exemplary embodiments. Further, the basic high pressure and low pressure sealing rings may be modified in accordance with known principles to include various grooves and other features to enhance sealing capabilities and characteristics. Additionally, the spring energizer may be made from materials other than stainless steel and related alloys. For example, elastomer materials which have low temperature spring characteristics similar to metal springs may be used. Such elastomers are generally not suitable for use as the low pressure sealing ring because of poor physical properties. However, such elastomers do provide good spring characteristics at extremely low temperature and may be used in place of a metal spring. A silicone elastomer is an example of the type of elastomer which can be used as the spring energizer. Accordingly, the present invention is not limited to the specific embodiments as illustrated herein, but is only limited by the following claims.

What is claimed is:

1. In a multi-element seal for sealing the space between two relatively reciprocating and/or surfaces at both high and low pressure, said seal having a low pressure sealing ring extending between and contacting both reciprocating surfaces and a high pressure sealing ring which also extends between and contacts both reciprocating surfaces wherein said low pressure sealing ring is made of an elastomer which provides a sealing bias against said high pressure sealing ring and said reciprocating surfaces within a given range of temperatures, the improvement comprising:

a spring energizer located annularly within said low pressure sealing ring to increase the sealing bias of said low pressure sealing ring against said high pressure sealing ring and reciprocating surfaces at temperatures outside said range of temperatures at which said elastomer provides a sufficient sealing bias for sealing by said low pressure and high pressure sealing rings.

2. An improved multi-element seal according to claim 1 wherein said spring energizer is a metallic spring energizer.

3. An improved multi-element seal according to claim 2 wherein said high pressure sealing ring includes a first portion which extends between and contacts both reciprocating surfaces and a second portion which has a seal surface which contacts one of said reciprocating surfaces and a seating surface which contacts said low pressure sealing ring, said second portion being located between said low pressure sealing ring and one of said reciprocating surfaces, and wherein said low pressure sealing ring includes a bias portion located radially

adjacent to said seating surface of said high pressure sealing ring and a low pressure sealing portion, said metallic spring energizer being located in said sealing portion of said low pressure sealing ring.

4. An improved multi-element sealing ring according to claim 3 wherein said seating surface of said high pressure sealing ring includes a first surface extending axially from said first portion of said high pressure sealing ring and a second surface which slopes angularly between said first surface and said seal surface.

5. An improved multi-element seal according to claim 1 wherein said low pressure sealing ring consists essentially of rubber.

6. An improved multi-element seal according to claim 2 wherein said metallic spring energizer is a slant coil spring.

7. An improved multi-element seal according to claim 2 wherein said metallic spring energizer is a cantilever beam spring.

8. An improved multi-element seal according to claim 2 wherein said metallic spring energizer is a helical spring.

9. An improved multi-element seal according to claim 2 wherein said metallic spring is a marcel expander.

10. An improved multi-element seal according to claim 2 wherein said low pressure sealing ring includes an axially extending surface which defines an axial

opening extending radially over the seating surface of said high pressure sealing ring for receiving said metallic spring energizer.

11. In a method for sealing the space between two relatively reciprocating and/or rotating surfaces at both high and low pressures wherein a high pressure sealing ring and an elastomeric low pressure sealing ring provide said sealing and wherein said low pressure sealing ring provides biasing of at least a portion of said high pressure sealing ring against at least one of said reciprocating surfaces within a given range of temperatures, the improvement comprising providing said low pressure sealing ring with a spring energizer located annularly within said low pressure ring to increase the sealing bias of said low pressure sealing ring against said high pressure sealing ring and said reciprocating surfaces at temperatures outside said range of temperatures at which said elastomer provides a sufficient sealing bias for sealing by said low pressure and high pressure sealing rings.

12. An improved method according to claim 10 wherein said spring energizer is a metallic spring energizer.

13. An improved method according to claim 12 wherein said metallic spring energizer is a slant coil spring.

14. An improved method according to claim 12 wherein said metallic spring energizer is a cantilever beam spring.

15. An improved method according to claim 12 wherein said spring energizer is a helical spring.

16. An improved method according to claim 12 wherein said spring energizer is a marcel expander.

Fig. 1.

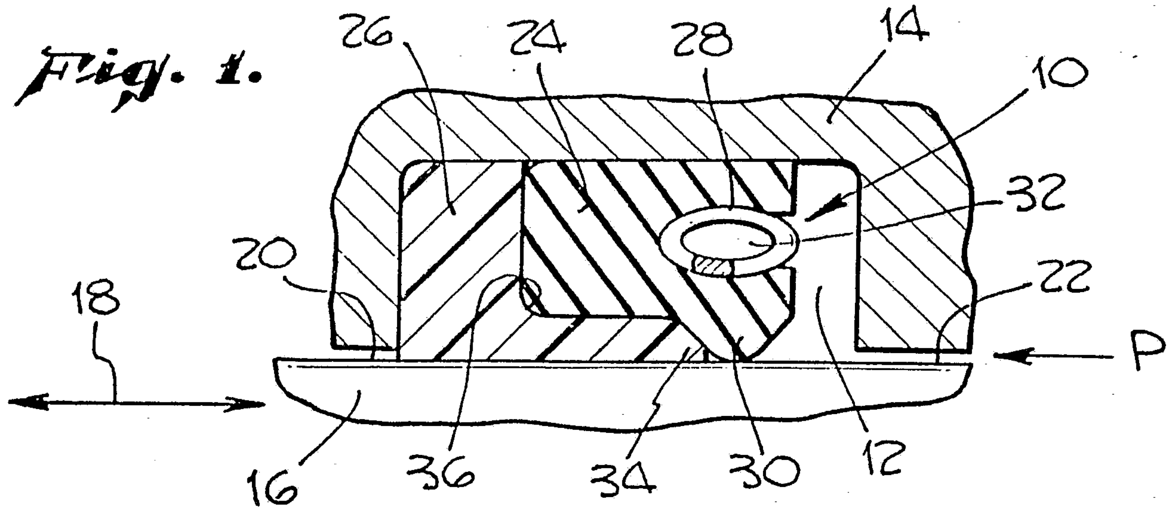

Fig. 2.

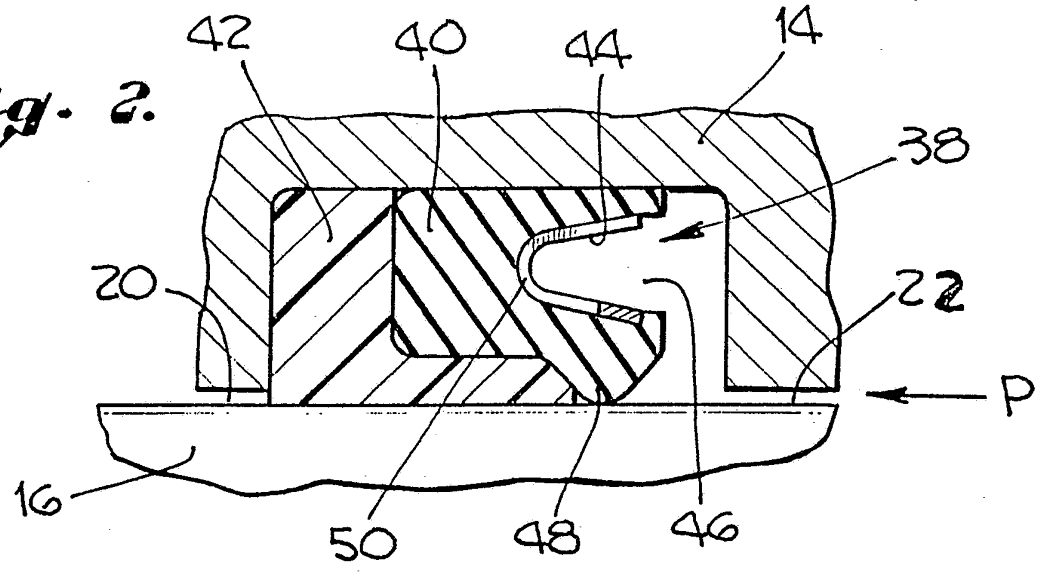

Fig. 3.

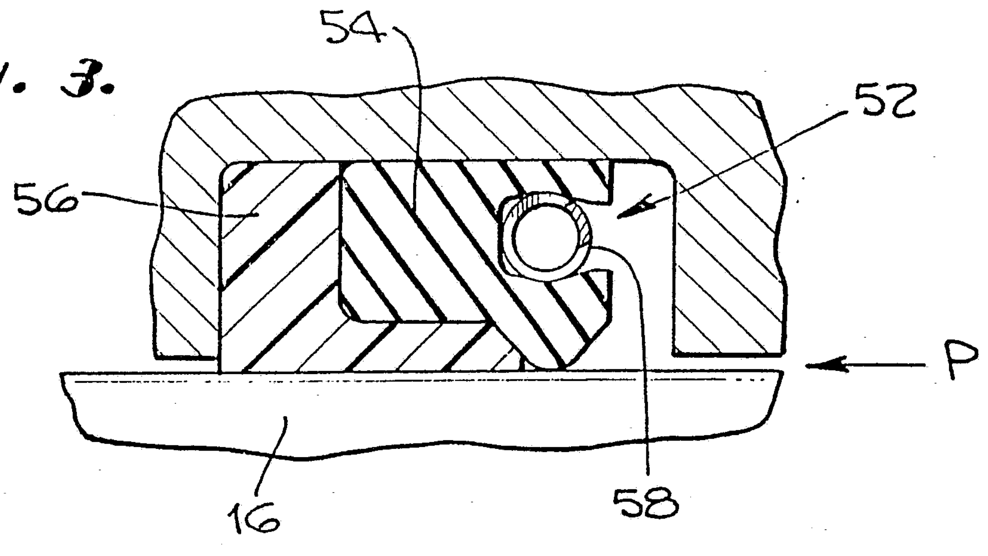

Fig. 4.

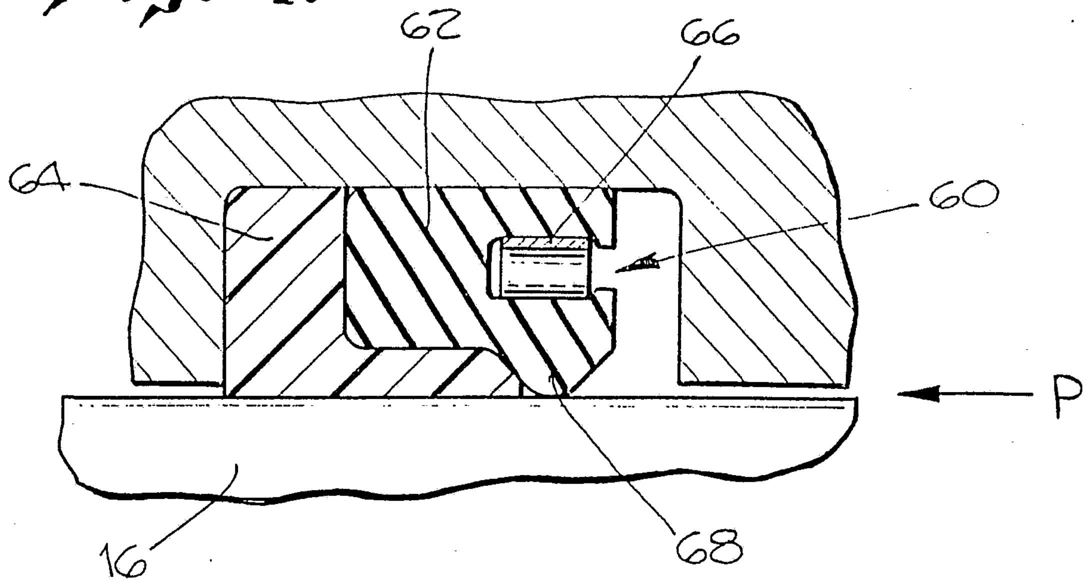

Fig. 5.

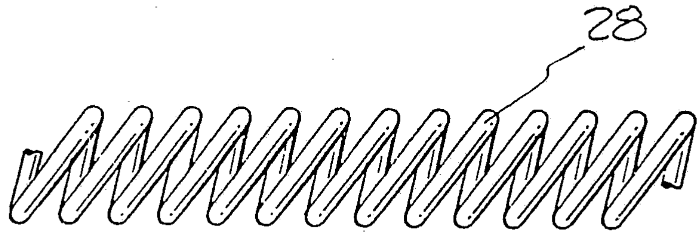

Fig. 6.

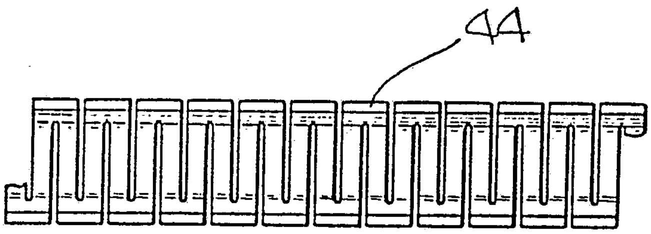

Fig. 7.

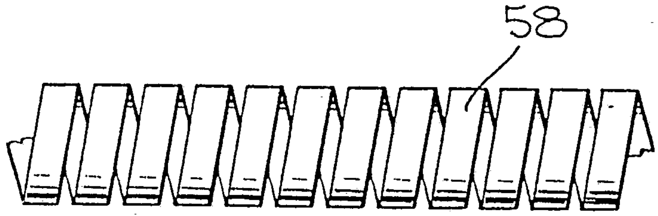

Fig. 8.

INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/07682

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): F16J 15/32; F16J 15/54; F16J 15/56

US CL: 277/1; 277/158, 159, 163, 165, 205, 188.A

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
US CL.	165,205,176,177,194,188A, 121, 157, 158, 160, 163, 164, 1

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
Y	GB, A, 2,029,913, Course 26 MARCH 1980 (see entire document).	1-16
Y	US, A, 4,706,970, Ramirez 17 November 1987 (see figures 1 and 3)	1-5, 7,11,12 14
Y	FR, A, 1,231,867, D.O.P. 04 October 1960 (See Figures 1-12)	1-5,7,11,12,14
Y	US, A, 3,653,670, Sifri, et al 04 April 1972 (see Figures 1 and 4)	1-5,8, 10-12 15
Y	US, A, 4,655,462, Balsells 07 April 1987 (see Figures 1 and 8)	1-6, 10-13
Y	DE, C, 700,403, Haug 19 December 1940 (See Figures 1-9)	1-5,9,11,12,16
Y	US, A, 3,765,690 Sievenpiper 16 October 1973 (see entire document)	3,4
A	US, A, 4,231,578, Traub 04 November 1980	
A	US, A, 4,268,045, Traub 19 May 1981	

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
20 February 1991	15 APR 1991
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/US	Allan N. Shoap, Primary Examiner

Form PCT/ISA/210 (second sheet) (May 1986)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	US,A, 4,566,702, Traub	
A	US,A, 1,718,338, Traub 27 February 1973	
A	US, A, 3,527,507, Clark et al 08 September 1970	

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers , because they relate to subject matter [1] not required to be searched by this Authority, namely:

2. ☐ Claim numbers ... , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [1], specifically:

3. ☐ Claim numbers___________, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

International Application No. PCT/US90/07682

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No [18]
A	US, A, 3,084,944, Stucke 09 April 1963	
A	US, A, 4,051,166, Domkowski 11 October 1977	
A	JP, A, 61-256066 Nakabayashi 13 November 1986	
A	GB, A, 695,408, Dutton-Forshaw 12 August 1953	
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