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(56) Documents Cited:
GB 2053319 A **CN 202392109 U**
DE 002926660 A1 **US 20110293404 A1**

(58) Field of Search:
INT CL **F03B, F16J, F16N**
Other: **WPI, EPODOC**

(54) Title of the Invention: **Cylinder seal**
Abstract Title: **Passive lubricant pressure control for cylinder seal**

(57) A seal 16 for use in a piston and cylinder arrangement 1 includes a reservoir 20 supplying lubricant between parts that are in sealing contact and in motion relative to each other. The reservoir 20 is provided with pressure adjusting means 21, 22, 24 which vary the lubricant pressure within the reservoir in response to the changing pressure of a working fluid e.g. in the chamber 12. Part of the reservoir wall may be flexible 21 and in fluid communication with the working fluid via a passage 24. Since the lubricant and working fluid are at the same pressure, leakage or contamination of the lubricant can be reduced and a wiper seal 26 may be designed for only low pressure use. The arrangement may be used in hydraulic systems for wave or tidal energy conversion.

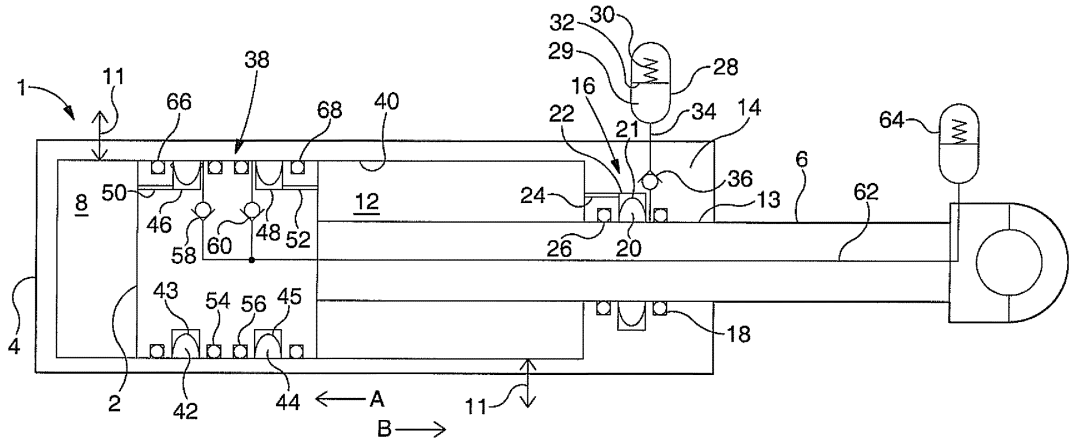

Fig. 1

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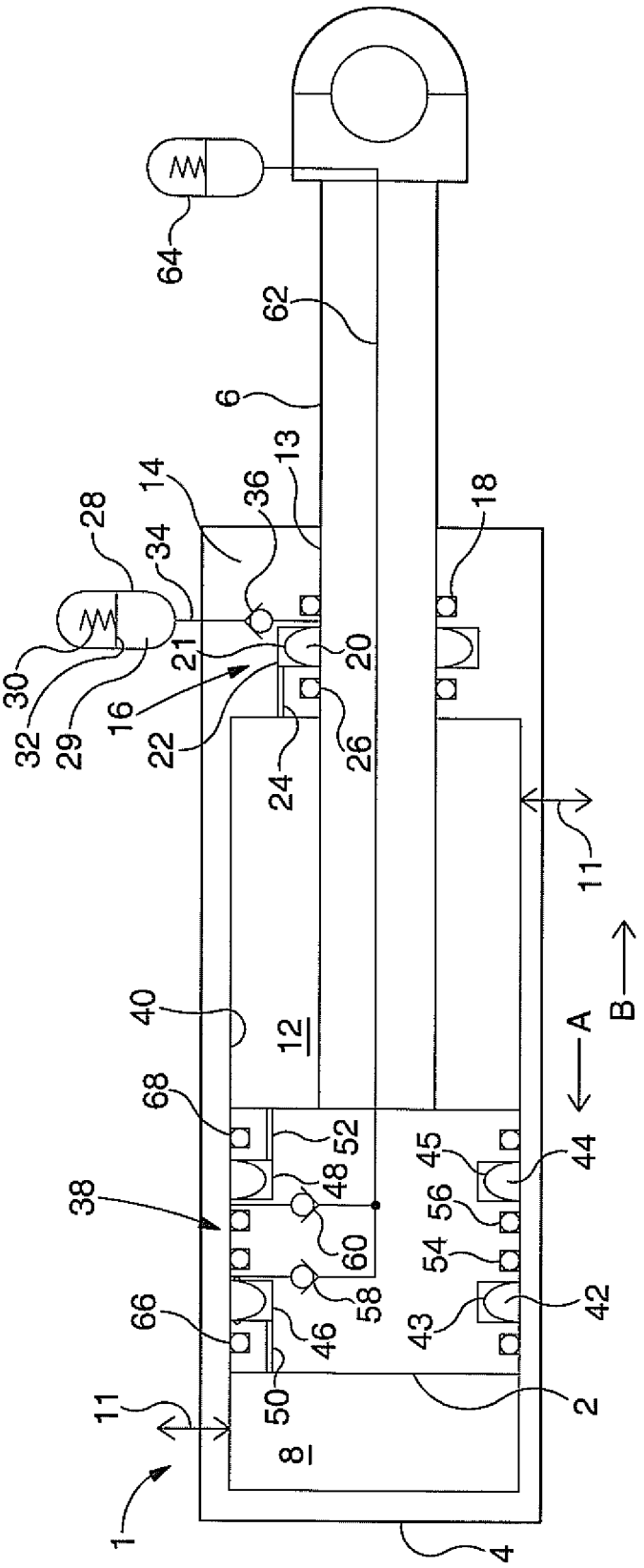
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Fig. 1

Cylinder Seal

Field of the invention

The present invention relates to seals suitable for use in piston and cylinder arrangements, in particular hydraulic systems such as, for example, those that may be employed in the conversion of wave or tidal energy to electrical energy.

Background to the Invention

For efficient operation, piston and cylinder arrangements require adequate sealing between the piston and the walls of the cylinder to prevent unwanted passage of working fluid past the piston as it moves backwards and forwards in the cylinder. The working fluid is the gas or liquid being pumped by the piston, or that causes the piston to move.

Sealing may also be required in other locations, for example where a connecting rod that drives a piston exits through an aperture in the end of a cylinder and unwanted escape of working fluid from the cylinder through the aperture is to be prevented.

Providing effective and durable sealing between parts moving relative to each other can be difficult, good lubrication is required to prevent wear and avoid energy losses to friction.

Time required repairing and maintenance piston and cylinder arrangements represents a significant economic cost. These costs can be particularly high where the piston and cylinder arrangement is located underwater, for example being used to convert energy derived from wave or tidal action into electrical energy.

Systems making use of hydraulic piston and cylinder arrangements in wave energy conversion devices are described for example in WO2006/100436 and WO2010/084305, (both patent applications by the present applicants). In such systems a hydraulic circuit includes a piston driven in a cylinder by the oscillations of a flap portion in response to wave action. .In such systems the working fluid (hydraulic fluid) may be (sea) water, which has the advantage of being freely available and non-polluting.

Whilst the systems described in WO2006/100436 and WO2010/084305 provide practical means for extracting energy from waves there is an ongoing need for improved and/or alternative apparatus and methods to improve ease of installation, control and maintenance.

Description of the Invention

The present invention provides a seal for use in a piston and cylinder arrangement, the seal comprising:

a reservoir supplying lubricant between surfaces of parts that are, in use of the piston and cylinder, in sealing contact and in motion relative to each other; wherein

the reservoir is provided with pressure adjusting means formed an arranged to vary the pressure within the reservoir in response to the changing pressure of a working fluid in the cylinder that is restrained by the seal.

The present invention also provides a reservoir for use in a seal of the invention.

The present invention also provides a piston in cylinder arrangement including at least one seal of the invention.

A seal of the invention may be provided for example between the circumferential surface of a piston and the corresponding cylinder wall. Typically the reservoir will then be carried in the piston, supplying lubricant between the piston and the cylinder wall. This supplies lubricant between the piston surface and the cylinder wall and also to other seal components, that may be present, such as sealing elements that are typically used to provide improved sealing. A sealing element is a component that provides good sealing contact between moving parts i.e. a physical barrier to fluid flow between the two surfaces which are moving relative to each other. A sealing element may in the form of a rigid or relatively rigid structure such as a piston ring or a flexible structure, such as an 'O' ring. A flexible O ring may be, for example, of an elastomer. More than one sealing element may be employed in a seal.

For further example the seal may be provided between a connecting rod that drives a piston and its passage through an end wall of the cylinder. Typically the reservoir will be provided in the end of the cylinder. This supplies lubricant between the connecting rod surface and the passage through the end wall of the cylinder and also to other seal

components, such as seal elements, that are typically used to provide improved sealing. Seal elements employed may be, for example, one or more O rings.

Thus the seal may further include one or more seal elements such as O rings or piston rings to provide good sealing contact between moving parts. Typically the seal of the invention finds use where seals resistant to relatively high pressures (and changes in pressure) are required. In such cases at least one sealing element, such as an O ring, piston ring or other sealing element, selected for high pressure use, will usually be employed in the seal. Other sealing elements, for example forming low pressure "wiper seals" (as discussed below) may also be included.

The reservoir will generally be arranged to supply lubricant between the working fluid and the part of the seal including the most effective sealing contact. For example where sealing elements such as O rings or piston rings are employed for sealing under high pressure conditions, the reservoir will generally be arranged to supply lubricant to the high pressure side of the element or elements. Thus the lubricant can be constantly supplied between the working fluid and the sealing element or elements providing the high pressure seal.

However, more than one reservoir may be employed, for example one at each side of a sealing element or plurality of sealing elements. Such an arrangement can be of particular advantage where working fluid that produces high pressures can be found at both sides of a seal. For example in a double action hydraulic piston in cylinder arrangement, where working fluid flows in and out of the cylinder chamber on both sides of the piston. The piston may be fitted with two reservoirs having a sealing element or elements located between them, as described below with reference to an embodiment.

The seal can provide a number of advantages. The reservoir may contain a lubricant that has properties that differ from those of the working fluid used in the piston and cylinder arrangement. A hydraulic system for the transmission of power may make use of water or another liquid. The water or other liquid (the working fluid) may not have particularly good lubricating properties, resulting in undesirably rapid wear between moving parts and the requirement for increased maintenance and/or the requirement for especially durable materials for surfaces that are in motion and sealing contact. This

can be particularly relevant where water is used as the working fluid, such as in offshore wave or tidal power systems. Where a seal of the invention is used the reservoir can supply a lubricant, for example an oil or a grease, which is selected for lubrication properties rather than hydraulic duties. As a relatively small quantity of lubricant is required improved lubrication can be provided at relatively low cost. Where water is used as the working fluid and oil as lubricant, then the relatively small quantity of lubricant in use will reduce the potential environmental impact in the event of a leakage. In addition the working fluid employed may be of a generally lower quality than required when it is also used as lubricant.

The provision of the pressure adjusting means enables continuity of lubricant supply to the sealing surfaces of moving parts. It also acts to avoid ingress of the working fluid into the seal as pressure rises. Pressure within a typical piston and cylinder arrangement varies cyclically as the working fluid is pumped in and out of the cylinder. Where a higher pressure is generated the working fluid will tend to be forced into the seals e.g. between the piston sides and the cylinder wall or between a connecting rod and the sides of an aperture in the cylinder or other bearing it passes through. Thus the lubricant may be displaced from between moving surfaces in sealing contact, resulting in a loss of good quality lubrication. By varying the pressure within the reservoir in response to the varying pressure in the working fluid the pressure of lubricant at the seal can be kept sufficiently high to avoid this issue.

Conveniently the pressure adjusting means is formed an arranged to vary the pressure within the reservoir so as to be substantially the same as, or the same as, that of working fluid that is being restrained by the seal. This means that the pressure of the lubricant is, or is substantially, the same as that of the adjacent working fluid at any given time. This will act to prevent either the lubricant or the working fluid from being displaced. Desirably, low pressure sealing elements (forming wiper seals) may be provided to aid the separation of the working fluid from the lubricant as further described hereafter with reference to specific embodiments.

Pressure adjustment may be achieved by providing a reservoir that has at least a portion of wall that is moveable and is in fluid communication with the working fluid. The pressure of the working fluid acts on the outside of the moveable portion of wall.

Thus the moveable portion of wall or moveable wall is pressurised by the working fluid, transmitting the pressure of the working fluid to the lubricant within the reservoir.

Conveniently the reservoir may include a flexible portion of wall or may have a wall that is flexible. For example the reservoir may be in the form of a flexible container or "boot", constructed of an elastomeric material such as a natural or synthetic rubber. The flexible container can supply lubricant to the moving and sealing surfaces, via an open end, for example. The pressure of the working fluid being restrained by the seal is directed onto the outside of the flexible container, for example via a passage, communicating to the body of working fluid. Where the reservoir is located in a piston or in a wall or an end of the cylinder, the passage may be provided in the body of the piston or the cylinder as appropriate.

Other arrangements may be used, for example the reservoir may include a portion that is of bellows type construction or the reservoir may be substantially all or all of a bellows construction. The bellows reduces in volume as pressure is applied, typically from the working fluid. For further example the reservoir may be of generally rigid construction but having a wall portion that is itself a piston. Such a piston is a moveable portion of reservoir wall and can conveniently be pressurised at one side by the working fluid to consequently pressurise the lubricant within the reservoir.

Alternatively the pressure adjusting means can adjust the pressure of lubricant by other methods. For example by a pump, acting on the lubricant, that may cycle the pressure in the reservoir in sympathy with the anticipated cyclic variation in working fluid pressure in the cylinder.

Some loss of lubricant from the seal can be expected over time. Therefore the provision of means to resupply the lubricant is advantageous. A convenient way of supplying fresh lubricant is to provide a lubricant resupply reservoir.

The lubricant resupply reservoir is in fluid communication with the seal, for example by means of a pipe or passage that can deliver fresh lubricant to the seal as required. The fresh lubricant may be supplied to the reservoir of the seal or to some other appropriate location, for example between the circumferential surface of a piston and the corresponding cylinder wall, where the lubricant is in use. If convenient the

lubricant resupply reservoir may be located at some distance from the piston and cylinder arrangement. For example above water level or even on land when the piston and cylinder arrangement is below water level and in use on a wave or tidal power system.

The supply of fresh lubricant as required may be automatic. For example the resupply reservoir may be pressurised (typically to a relatively low pressure) but lubricant is prevented from flowing to the seal by a non-return valve in the pipe. The non-return valve remains closed as long as the pressure in the seal (the pressure of the lubricant in the seal) remains above a set value. When the pressure of lubricant in the seal is decreased below the set value the non-return valve opens to resupply lubricant.

Brief Description of the Drawings

Figure 1 shows in schematic cross section a piston and cylinder arrangement including seals of the invention.

Detailed Description of the Invention

Figure 1 shows in schematic cross section an example piston in cylinder arrangement 1 incorporating seals according to the invention. Such an arrangement may be used for example in a hydraulic circuit connected to a wave power energy conversion device.

The arrangement 1 includes a piston 2 in cylinder 4. the cylinder is driven back and forth as indicated by arrows A and B by means of a connecting rod 6 that connects to a wave energy capture device (not shown here, for example as shown in WO2006/100436 or WO2010/084305). The arrangement is double acting with working fluid (water) being alternately drawn into and then expelled from the spaces 8,12 to either side of the piston 2, via input/output ports indicated by double headed arrows 11, in the cylinder 4. Input and output of working fluid can be controlled by appropriate valving arrangements, in the known manner. Thus working fluid in both spaces 8 and 12 experiences cyclic rise and fall in pressure, depending on the direction of piston movement. The working fluid is therefore pumped by the arrangement shown, typically to drive a turbine connected to an electrical generator, for example.

An aperture 13 in the cylinder end 14 allows the connecting rod 6 to exit. A seal generally indicated by reference numeral 16 acts to prevent working fluid escaping through the aperture 13, that would result in a loss of pressure and energy generation.

The seal in this example includes, as a sealing element, a high pressure resisting O ring 18 seated in an annular groove of the end 14 of the cylinder 4. The O ring may be of an elastomer or may be replaced in some examples by a piston ring type of arrangement - a radially inwardly compressible metal ring, sitting in the annular groove.

The O ring 18 provides good sealing contact between the aperture 13 and the connecting rod 6 as it reciprocates backwards and forwards. An annular shaped reservoir 20 containing lubricant is provided in another annular groove 22 of the cylinder end.14. The reservoir 20 has a flexible (e.g. rubber) wall 21 and is open to the connecting rod 6. Annular groove 22 is in fluid communication with space 12 via passage 24. Thus the pressure of the working fluid in space 12 acts on flexible wall 21 to pressurise lubricant within the reservoir 20.

The lubricant from the reservoir lubricates the space between the connecting rod 6 and the wall of aperture 13 and hence the O ring 18 to connecting rod 6 sealing contact is also lubricated.

As the pressure of lubricant at the seal is or is substantially the same as that of the working fluid within space 12 (as it varies with time), ingress of working fluid into the seal 16 is avoided. A further sealing element, in this example O ring 26 is provided in another annular groove, between the reservoir 20 and space 12. This O ring is a wiper seal, acting to keep lubricant on the surface of connecting rod 6 out of the space 12 and to keep working fluid in space 12 out of seal 16. Wiper seal 26 may be designed only for relatively low pressure duty, as the pressure of the lubricant in seal 16 will be kept same or substantially the same as the pressure of working fluid in space 12 by means of passage 24 communicating pressure changes to reservoir 20.

Over time some loss of lubricant from the seal may be expected. Such losses are replenished by use of lubricant resupply reservoir 28, shown schematically in the drawing. The reservoir 28 holds a supply of fresh lubricant 29 that is pressurised slightly by, in this example, spring 30 acting on plate or piston 32. Lubricant 29 is

delivered to the seal by means of pipe 32 that includes a non-return valve 36. As long as pressure in the seal reservoir 20 remains higher than that of a preset value, no fresh lubricant will be delivered. However when the pressure in the reservoir 20 is sufficiently low, (due to loss of lubricant) and when the pressure in space 12 is also low, (the piston 2 is moving in the direction of arrow A, and working fluid is being drawn into space 12) the non-return valve will open and fresh lubricant is supplied to seal 16.

The piston 2 of the arrangement 1 is also supplied with a seal 38, generally of the same form as that of seal 16, but formed for use where working fluid is present at both sides of the seal, in spaces 8 and 12. Seal 38 provides sealing between the piston and inner wall 40 of the cylinder 4. In this example two reservoirs 42, 44 each with a flexible wall 43, 45 are provided. The reservoirs 42, 44 are each located in an annular groove 46, 48 on the piston 2 to either side of two sealing elements, high pressure resisting O rings 54 and 56. Sealing elements in the form of two high pressure resisting O rings are provided in this example but only one or alternatively more than two O rings could be employed. Other forms of sealing elements could also be used, for example piston rings.

The reservoirs 42, 44 are situated in annular grooves 46, 48 in the piston and each groove 46, 48 is in fluid communication via a passage 50, 52 to the respective adjacent cylinder space 8, 12 containing working fluid. Fresh lubricant is provided to seal 38 from lubricant resupply reservoir 64 that takes the same form as the resupply reservoir 28 used for seal 16. The fresh lubricant is supplied via pipe 62 travelling through connecting rod 6 and including non-return valves 58 and 60 in branches of pipe 62. Fresh lubricant will be delivered when pressure drops low enough to open one or other or both of the non-return valves 58, 60 in a similar fashion to that described above for seal 16.

The seal 38 also includes sealing elements forming wiper seals, O rings 66 and 68 provided in annular grooves of the piston 2 that act to keep lubricant on the surface of piston 2 out of the spaces 8, 12 and to keep working fluid in spaces 8, 12 out of seal 38. The wiper seals may be designed only for relatively low pressure duty, as the pressure of the lubricant to either side of O rings 54,56 will be kept same or substantially the same as the pressure of working fluid in corresponding adjacent

spaces 8, 12; by means of passages 50 and 52 communicating pressure changes to the reservoirs 42, 44.

In use seal 38 operates in similar fashion to that of seal 16. The reservoirs 42, 44 provide lubricant between the piston 2 and the inner wall 40 of the cylinder and hence between high pressure O rings 54, 56 and the inner wall 40. The pressure of each reservoir is adjusted via passages 50 or 52 to be the same or substantially the same as that of the working fluid in the cylinder space 8 or 12 nearest the respective reservoir. The sealing elements, O ring seals 54, 56, are protected from the working fluid by the reservoirs to either side. The wiper seals, O rings 66, 68, act to keep the lubricant from intermingling with the working fluid and vice versa.

It will be understood that the present invention has been described above purely by way of example, and modifications of detail can be made within the scope of the invention.

Each feature disclosed in the description and (where appropriate) the claims and drawings may be provided independently or in any appropriate combination.

Key with commentary to certain features of the drawings:

Part Number	Name	Commentary
8,12	Spaces to either side of the piston	Water
24, 50,52	Passage	Pilot hole connecting the cylinder/annulus to the volume under the rubber boot holding the oil reservoir. Oil pressure is same as the connecting chamber.
21,43,45	Flexible wall	Flexible rubber boot to hold oil reservoir.
20,42,44	Reservoir	Oil reservoir.
28,64	Lubricant resupply reservoir	Sprung loaded low pressure top up oil reservoir. There will be some loss of oil over time. This will maintain a full charge of oil. Ideally the top up system could be pipe back to shore via a small capillary tube, possibly only a few mm in diameter.
36,58,60	Non-return valve	Check valve allows top up of oil into annular gap between the cylinder the rod/piston the high pressure seal and the reservoir. Top up occurs during the low pressure suction stroke. The check valve prevents reverse flow on the high pressure stroke.
18,54,56	High pressure resisting O ring	High pressure seals, conventional elastomeric or could be piston rings. These seals will be working with oil so life will be significantly better than current water seals.
26,66,68	Wiper seal	Low pressure wiper seals. The function of these seals is to hold the oil reservoir in position. There will be very low differential pressure across these seals. These seals will benefit from oil lubrication. These seals will have significantly better life than current seal due to oil lubrication and low operating pressure.

CLAIMS:

1. A seal for use in a piston and cylinder arrangement, the seal comprising:

a reservoir supplying lubricant between surfaces of parts that are, in use of the piston and cylinder, in sealing contact and in motion relative to each other; wherein

the reservoir is provided with pressure adjusting means formed an arranged to vary the pressure within the reservoir in response to the changing pressure of a working fluid in the cylinder.

2. The seal according to claim 1 further comprising at least one sealing element providing sealing contact between moving parts.

3. The seal according to claim 1 wherein the at least one sealing element is an O ring or a piston ring.

4. The seal according to any preceding claim wherein the reservoir contains a lubricant that has different properties from that of the working fluid.

5. The seal according to any preceding claim wherein the pressure adjusting means is formed and arranged to vary the pressure within the reservoir so as to be substantially the same as that of the working fluid being restrained by the seal.

6. The seal according to any preceding claim wherein the pressure adjusting means comprises a moveable portion of the reservoir wall to outside of which the pressure of the working fluid is directed.

7. The seal according to claim 6 wherein the reservoir has a wall including a flexible portion or a wall that is flexible.

8. The seal according to claim 6 or claim 7 wherein the working fluid is directed to the outside of the moveable portion of reservoir wall via a passage in a piston or in the wall of a cylinder, of the piston and cylinder arrangement.

9. The seal according to claim 6 wherein the moveable portion of reservoir wall is a piston.

10. The seal according to claim 6 wherein the moveable portion of reservoir wall takes the form of a bellows or the reservoir is a bellows.

11. The seal according to any preceding claim further comprising at least one wiper seal, provided between the working fluid and the lubricant to aid their separation.

12. The seal according to any preceding claim further comprising a second reservoir for supplying lubricant.

13. The seal according to any preceding claim further comprising a lubricant resupply reservoir for delivering fresh lubricant to the seal.

14. A piston in cylinder arrangement including at least one seal according to any one of claims 1 to 13.

15. The piston in cylinder arrangement of claim 14 wherein the at least one seal is provided between a piston and the corresponding cylinder wall.

16. The piston in cylinder arrangement of claim 14 wherein the at least one seal is provided between a connecting rod of the piston and a passage through the end wall of the cylinder.

Application No:	GB1216114.7	**Examiner:**	Mr Peter Middleton
Claims searched:	1-16	**Date of search:**	12 March 2013

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-16	US2011/293404 A1 (GESTION) see abstract and figures: underwater turbine with pressure-balanced lubrication
X	1-16	DE2926660 A1 (HOWALDTSWERKE) see WPI abstract and figures: shaft seal with oil pressure adjusted with respect to water pressure
X	1-16	GB2053319 A (DRESSER) see abstract and figures: example of drilling tool with pressure balanced lubrication
X	1-16	CN202392109 U (AEROSPACE) see EPODOC abstract and figures: example of drilling tool with pressure balanced lubricant supply

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

F03B; F16J; F16N

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC

International Classification:

Subclass	Subgroup	Valid From
F03B	0013/18	01/01/2006
F16J	0001/08	01/01/2006
F16J	0015/16	01/01/2006
F16N	0009/04	01/01/2006