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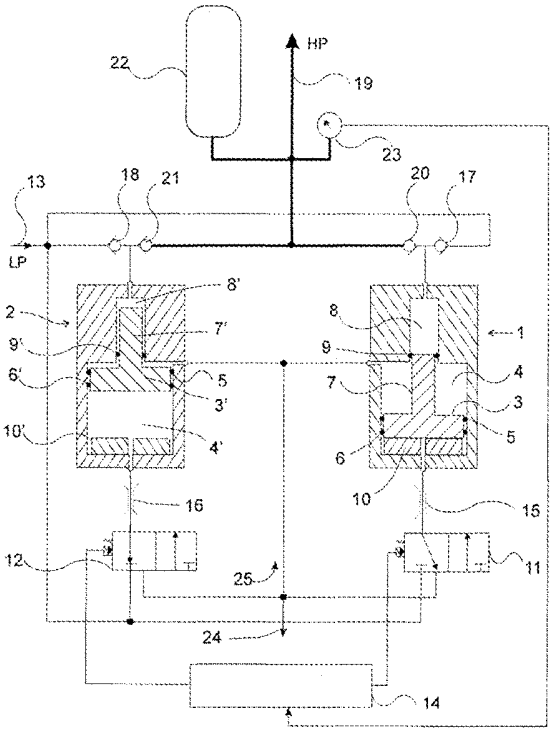
***F04B 9/105*** (2006.01) ***F04B 9/109*** (2006.01)

(56) Documents Cited:
**GB 2198081 A** **GB 1450473 A**
**EP 1138872 A** **EP 0654330 A1**

(58) Field of Search:
UK CL (Edition X) **F1D**
INT CL **E21B, F04B, F15B**
Other: **OPTICS, WPI, EPODOC, TXTE**

(54) Abstract Title: **Subsea hydraulic intensifier with supply directional control valves electronically switched**

(57) A modular hydraulic intensifier comprises a piston and cylinder assembly 1 having a first piston 3 in a chamber 4 of low pressure cylinder and a second piston 7 in a chamber 8 of a high pressure cylinder. The pistons are coupled together and the first piston has a larger cross-sectional area than the second piston. A high pressure output 19 and optional accumulator 22 are coupled to the high pressure cylinder chamber. There are means 13 for supplying low pressure hydraulic fluid to the low pressure cylinder chamber, an electrically operated directional control valve 11 for controlling the supply of low pressure hydraulic fluid to the chamber of the low pressure cylinder; and electronic means 14 for controlling operation of the directional control valve. The electronics may form part of an existing subsea control module and the intensifiers may be provided in alternating pairs.

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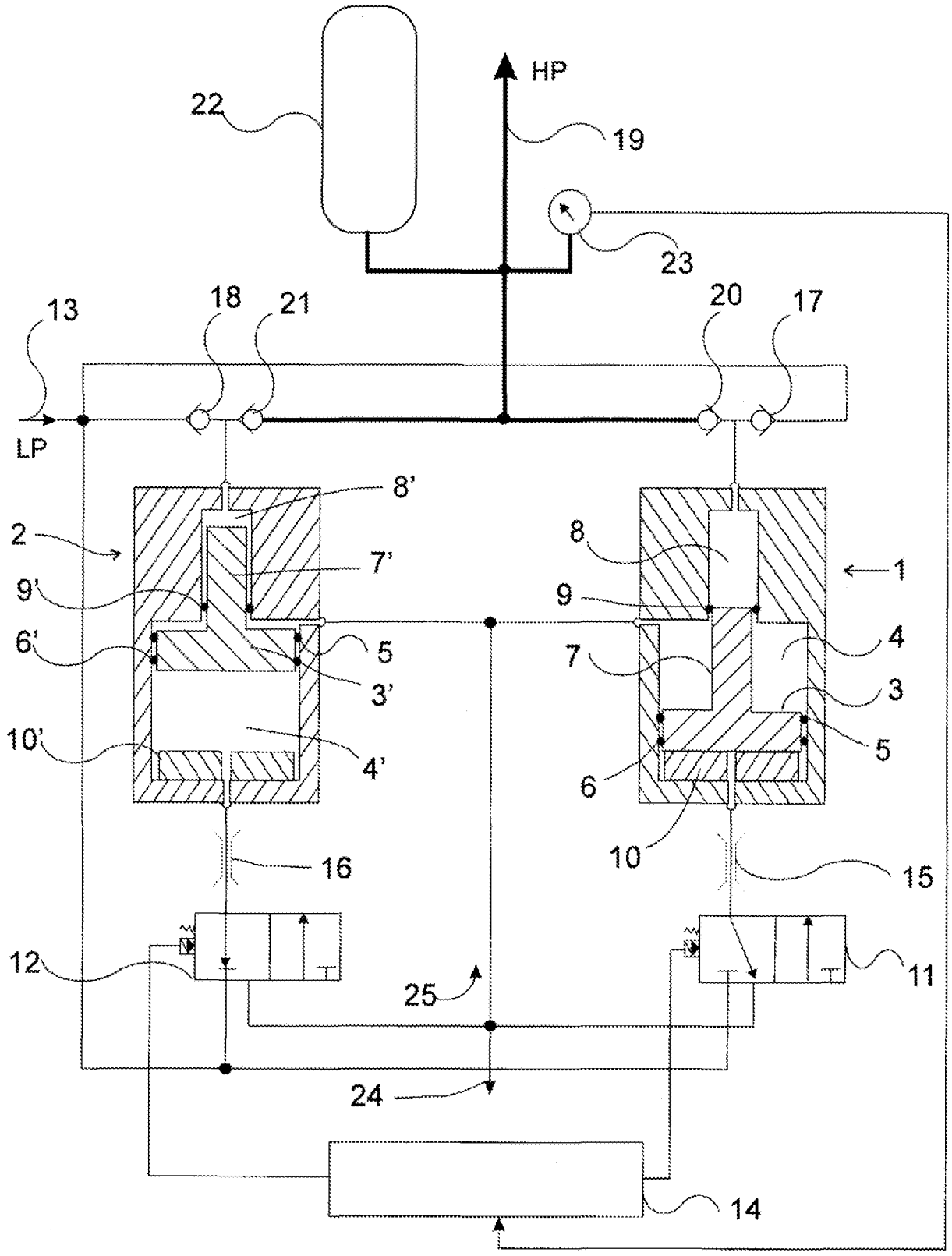
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# HYDRAULIC INTENSIFIERS

The present invention relates to hydraulic intensifiers.

Hydraulic intensifiers are devices that generate high hydraulic pressure from a low pressure source. They are, typically, employed in subsea wells such as hydrocarbon production or injection wells, to provide a source of high pressure hydraulic fluid for the operation of hydraulically actuated devices, such as valves and flow control chokes. Such wells are, typically, supplied with low pressure hydraulic fluid, via an umbilical, which can be in excess of 100 Km in length The supply of high pressure fluid via the umbilical is not favoured by well operators, as a high pressure feed within the umbilical, needing a much greater wall thickness than usual, results in much greater umbilical and handling costs. Intensifiers use relatively large cross-sectional area pistons, operating at low pressure, to actuate small cross-sectional area pistons, to generate high pressures, thus utilising the mechanical advantage of the ratios of the piston cross-sectional areas to 'intensify' the pressure.

Typically, two sets of pistons are utilised which operate alternately to sustain a continuous flow of fluid. The alternate operation of the piston sets is controlled by a complicated arrangement of valves and springs and since these and the piston sets are integrated into one assembly, current hydraulic intensifiers are complicated devices, which are difficult to manufacture and thus of high cost. Furthermore, they are heavy devices, typically 37 Kg, and are prone to a multiplicity of problems which include failure of 'slipper' seals and changeover valves, sensitivity to contamination and a tendency to 'lock-up' due to pressure in their return lines. Repair requires the complete removal and strip down of the assembly which is also expensive, and new designs require full approval testing before they can be employed.

GB-A-2 275 969 discloses a hydraulic intensifier comprising two sets of high and low pressure pistons for the compression of low pressure liquid, the piston sets being coupled together by the slider of a pilot valve so as to act in mutual opposition, the low pressure pistons of the piston sets being driven by low pressure liquid supplied by way of a changeover valve and the changeover valve being changed over at the end of each stroke of the pilot valve to reverse the motion of the piston sets, the changeover valve being effective to maintain a supply of low pressure liquid to drive the piston sets throughout the stroke of the pilot valve.

According to the present invention from one aspect, there is provided a hydraulic intensifier comprising:

a piston and cylinder assembly having a first piston in a chamber of a low pressure cylinder and a second piston in a chamber of a high pressure cylinder, the first and second pistons being coupled together and the first piston having a larger cross-sectional area than the second piston;

a high pressure output coupled to the chamber of the high pressure cylinder;

means for supplying low pressure hydraulic fluid to the chamber of the low pressure cylinder;

an electrically operated directional control valve for controlling the supply of low pressure hydraulic fluid to the chamber of the low pressure cylinder; and

electronic means for controlling operation of the directional control valve.

Preferably, the hydraulic intensifier comprises:

a further such piston and cylinder assembly, the high pressure output being coupled to the chamber of the high pressure cylinder of the further piston and cylinder assembly; and

a further such directional control valve for controlling the supply of low pressure fluid from the supplying means to the chamber of the low pressure cylinder of the further piston and cylinder assembly, the electronic means controlling the directional control valves to supply low pressure fluid alternately to the chambers of the low pressure cylinders of the first and further piston and cylinder assemblies.

According to the present invention from another aspect, there is provided a hydraulic intensifier comprising:

a first piston and cylinder assembly having a first piston in a chamber of a low pressure cylinder and a second piston in a chamber of a high pressure cylinder, the first and second pistons being coupled together and the first piston having a larger cross-sectional area than the second piston;

a further such piston and cylinder assembly;

a high pressure output coupled to the chambers of the high pressure cylinders of the first and further piston and cylinder assemblies;

means for supplying low pressure hydraulic fluid to the chambers of the low pressure cylinders of the first and further piston and cylinder assemblies;

first and second electrically operated directional control valves for controlling the supply of low pressure hydraulic fluid to the chambers of the low pressure cylinders of the first and further piston and cylinder assemblies respectively; and

electronic means for controlling operation of the directional control valves to supply low pressure hydraulic fluid alternately to the chambers of said low pressure cylinders.

In this case, low pressure hydraulic fluid could be supplied to the chambers of the high pressure cylinders via respective ones of first and second check valves, said chambers of the high pressure cylinders being coupled with said high pressure output via respective ones of third and fourth check valves.

A hydraulic intensifier according to the invention could comprise means coupled to said electronic means for sensing pressure of hydraulic fluid at said high pressure output and causing the or each directional control valve not to supply hydraulic fluid to the chamber or chambers of the low pressure cylinder or cylinders in response to the sensed pressure being at a required value.

Said electronic means could comprise a bistable device.

A hydraulic intensifier according to the invention could comprise a hydraulic accumulator coupled with said high pressure output.

A hydraulic intensifier according to the invention could be one for use in a subsea well. In this case, said electronic means could be provided via a subsea electronics module for a subsea well and/or the or each directional

control value could be provided by a directional control valve of a subsea control module for a subsea well.

According to the present invention from a further aspect, there is provided a method of producing high pressure hydraulic fluid comprising:

providing a piston and cylinder assembly having a first piston in a chamber of low pressure cylinder and a second piston in a chamber of a high pressure cylinder, the first and second pistons being coupled together, the first piston having a larger cross-sectional area than the second piston and there being a high pressure output coupled to the chamber of the high pressure cylinder;

supplying low pressure hydraulic fluid to the chamber of the low pressure cylinder;

providing an electrically operated directional control valve for controlling the supply of low pressure hydraulic fluid to the chamber of the low pressure cylinder; and

electronically controlling operation of the directional control valve.

Preferably, the method comprises:

providing a further such piston and cylinder assembly, the high pressure output being coupled to the chamber of the high pressure cylinder of the further piston and cylinder assembly;

providing a further such directional control valve for controlling supply of low pressure fluid to the chamber of the low pressure cylinder of the further piston and cylinder assembly; and

electronically controlling the directional control valves to supply low pressure fluid alternately to the chambers of the low pressure cylinders of the first and further piston and cylinder assemblies.

The present invention enables a modular hydraulic intensifier which utilises standard approved directional control valves (DCVs) which are controlled electronically, in conjunction with piston sets sealed with proven standard approved seals. By being modular, such an intensifier can be serviced by the replacement of individual components, most of which are standard devices which will already be held as spares for the rest of the well control system.

The present invention will now be described, by way of example, with reference to the single figure of the accompanying drawing which shows diagrammatically an example of a hydraulic intensifier according to the invention.

The single figure of the accompanying drawing shows, diagrammatically, a hydraulic intensifier for a subsea hydrocarbon extraction or injection well. Two identical piston and cylinder assemblies 1 and 2 are shown in sectioned view, whereas the rest of the hydraulic circuitry is shown schematically. Each piston assembly has a large cross-sectional area piston 3 or 3' in the chamber 4 or 4' of a low pressure cylinder (sealed by standard approved sealing rings 5 and 6 or 5' and 6') and coupled to a smaller cross-sectional area piston 7 or 7' in the chamber 8 or 8' of a high pressure cylinder (sealed with an approved sealing ring 9 or 9'). The chamber 4 or 4' of each low pressure cylinder is fitted with a buffer 10 or 10', manufactured from a resilient, hydraulic fluid resistant material, to minimise the impact of a fast-returning piston. The operation of each of the piston assemblies 1 and 2, is controlled, alternately, by respective ones of standard solenoid-operated directional control valves (DCVs) 11 and 12, each of which is supplied by hydraulic fluid from a low pressure

(LP) source 13, typically via the well umbilical. The solenoids of the DCVs 11 and 12 are electrically energised alternately from a dc power source switched by a bistable electronic device 14 such as a multivibrator and each DCV is coupled to the chamber 4 or 4' of the respective low pressure cylinder via a respective restrictor 15 or 16.

Source 13 is also connected to the chambers 8 and 8' of the high pressure cylinders via check valves 17 and 18 respectively. Also, each of the chambers 8 and 8' is connected to a high pressure (HP) intensifier output line 19 via check valves 20 and 21 respectively, reference numeral 22 designating a hydraulic accumulator connected with line 19 and reference numeral 23 designating a pressure switch connected to device 14. Reference numeral 24 designates a return line for excess fluid.

The mode of operation of the intensifier is as follows.

After installation, low pressure hydraulic fluid from the source 13 primes the system and additionally provides a continuous supply of hydraulic fluid to the chambers 8 and 8' of the high pressure cylinders, via check valves 17 and 18 respectively. In the condition of the assemblies 1 and 2 and DCVs 11 and 12 as shown, the solenoid of DCV 11 has been de-energised and that of DCV 12 has been energised so that piston 3' has been driven by low pressure fluid that entered chamber 4'. Then, the solenoid of DCV 11 is energised by dc power, switched by the device 14, which allows low pressure hydraulic fluid to operate the piston 3 in the chamber 4 of the low pressure cylinder of the piston/cylinder assembly 1, the solenoid of DCV 12 being de-energised. The rate of movement of the piston 3 is controlled by the hydraulic restrictor 15. The resultant operation of piston 7 forces hydraulic fluid from the chamber 8 of the high pressure cylinder of assembly 1 at high pressure (HP), via check valve 20, to the intensifier output line 19 and into hydraulic accumulator 22. The

check valve 17 will close to isolate the generated high pressure from the low pressure source.

The piston 7' in the piston/cylinder assembly 2 will be forced downwards, with the hydraulic fluid transferring from the chamber 4' to the chamber 8' via the DCV 12, whose quiescent state is to switch flow via the return path as indicated by arrow 25, whilst at the same time the chamber 8' of the high pressure cylinder of assembly 2 is filled by the low pressure source 13 via the check valve 18. The transfer of fluid from chamber 4' to chamber 8', in the flow direction 25 minimises the consumption of hydraulic fluid.

At a pre-set time, the device 14, will change state, thus removing dc power from the solenoid of DCV 11 and applying dc power to the solenoid of DCV 12, allowing the low pressure fluid to operate the piston 3' in the piston/cylinder assembly 2, so that high pressure fluid is pumped via check valve 21 to the intensifier output line 19 and to the accumulator 22. Thus, the DCVs 11 and 12 operate alternately, providing alternate pumping by the piston/cylinder assemblies 1 and 2 of high pressure fluid to the accumulator 22. Excess fluid from the process is exhausted via return line 24 as for existing intensifiers. The pumping process continues until the required high pressure is achieved at the accumulator 22 as sensed by pressure switch 23, which then switches off the dc power to the DCV solenoids via device 14.

In practice, the device 14 may be dispensed with in a typical well installation, since control of the solenoids of the DCVs can be effected by the subsea control module (SCM) of the well. This module already houses DCVs and a subsea electronics module (SEM) to electronically control them, typically by an electronic processor driving power amplifiers to operate the DCV solenoids. It would therefore be a relatively simple addition to the SEM to incorporate the functions of the device 14 within the

software of the SCM processor, and the necessary solenoid power drivers to the SCM. Also, the intensifier DCVs could be housed in the SCM. Furthermore, the hydraulic accumulator 22 may not be necessary for some installations.

Although the above example of the invention uses a dual piston/cylinder arrangement, the intensifier could use a single piston/cylinder arrangement. However the twin arrangement described provides redundancy in the event of a failure and is therefore generally the preferred option.

Preferably, the DCVs are standard-approved devices, a main advantage of using the same to control the intensifier being that they would not require an expensive test for type approval in a subsea well environment.

Other advantages which are enabled by the invention are: modularity, which permits cost-effective repair; only two basic moving parts compared to existing designs that use a multiplicity of moving parts to mechanically provide the fluid switching sequences to operate the hydraulic pistons; cheaper manufacture as only two 'special' parts (piston/cylinder assemblies) are required; and the potential of using existing facilities (e.g. spare DCVs and/or processing power) within a SCM to operate the pistons.

**CLAIMS**

1. A hydraulic intensifier comprising:

a piston and cylinder assembly having a first piston in a chamber of a low pressure cylinder and a second piston in a chamber of a high pressure cylinder, the first and second pistons being coupled together and the first piston having a larger cross-sectional area than the second piston;

a high pressure output coupled to the chamber of the high pressure cylinder;

means for supplying low pressure hydraulic fluid to the chamber of the low pressure cylinder;

an electrically operated directional control valve for controlling the supply of low pressure hydraulic fluid to the chamber of the low pressure cylinder; and

electronic means for controlling operation of the directional control valve.

2. A hydraulic intensifier according to claim 1, comprising:

a further such piston and cylinder assembly, the high pressure output being coupled to the chamber of the high pressure cylinder of the further piston and cylinder assembly; and

a further such directional control valve for controlling the supply of low pressure fluid from the supplying means to the chamber of the low pressure cylinder of the further piston and cylinder assembly,

the electronic means controlling the directional control valves to supply low pressure fluid alternately to the chambers of the low pressure cylinders of the first and further piston and cylinder assemblies.

3. A hydraulic intensifier comprising:

a first piston and cylinder assembly having a first piston in a chamber of a low pressure cylinder and a second piston in a chamber of a high pressure cylinder, the first and second pistons being coupled together and the first piston having a larger cross-sectional area than the second piston;

a further such piston and cylinder assembly;

a high pressure output coupled to the chambers of the high pressure cylinders of the first and further piston and cylinder assemblies;

means for supplying low pressure hydraulic fluid to the chambers of the low pressure cylinders of the first and further piston and cylinder assemblies;

first and second electrically operated directional control valves for controlling the supply of low pressure hydraulic fluid to the chambers of the low pressure cylinders of the first and further piston and cylinder assemblies respectively; and

electronic means for controlling operation of the directional control valves to supply low pressure hydraulic fluid alternately to the chambers of said low pressure cylinders.

4. A hydraulic intensifier according to claim 3, wherein low pressure hydraulic fluid is supplied to the chambers of the high pressure cylinders via respective ones of first and second check valves, said chambers of the high pressure cylinders being coupled with said high pressure output via respective ones of third and fourth check valves.

5. A hydraulic intensifier according to any preceding claim, comprising means coupled to said electronic means for sensing pressure of hydraulic fluid at said high pressure output and causing the or each directional control valve not to supply hydraulic fluid to the chamber or chambers of the low pressure cylinder or cylinders in response to the sensed pressure being at a required value.

6. A hydraulic intensifier according to any preceding claim, wherein said electronic means comprises a bistable device.

7. A hydraulic intensifier according to any preceding claim, comprising a hydraulic accumulator coupled with said high pressure output.

8. A hydraulic intensifier according to any preceding claim, adapted for use in a subsea well.

9. A hydraulic intensifier according to claim 9, wherein said electronic means is provided via a subsea electronics module for a subsea well.

10. A hydraulic intensifier according to claim 8 or 9, wherein the or each directional control value is provided by a directional control valve of a subsea control module for a subsea well.

11. A method of producing high pressure hydraulic fluid comprising:

providing a piston and cylinder assembly having a first piston in a chamber of low pressure cylinder and a second piston in a chamber of a high pressure cylinder, the first and second pistons being coupled together, the first piston having a larger cross-sectional area than the second piston and there being a high pressure output coupled to the chamber of the high pressure cylinder;

supplying low pressure hydraulic fluid to the chamber of the low pressure cylinder;

providing an electrically operated directional control valve for controlling the supply of low pressure hydraulic fluid to the chamber of the low pressure cylinder; and

electronically controlling operation of the directional control valve.

12. A method according to claim 11, comprising:

providing a further such piston and cylinder assembly, the high pressure output being coupled to the chamber of the high pressure cylinder of the further piston and cylinder assembly;

providing a further such directional control valve for controlling supply of low pressure fluid to the chamber of the low pressure cylinder of the further piston and cylinder assembly; and

electronically controlling the directional control valves to supply low pressure fluid alternately to the chambers of the low pressure cylinders of the first and further piston and cylinder assemblies.

13. A hydraulic intensifier substantially as herein described with reference to the accompanying drawing.

14. A method of producing high pressure hydraulic fluid, substantially as herein described with reference to the accompanying drawing.

**Application No:** GB0811205.4 **Examiner:** James Paddock

**Claims searched:** 1-14 **Date of search:** 10 October 2008

# 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 | X:1-4,11,12, Y:6-9 | EP0654330 A1 DAIKIN See Figures 1 and 3. Two 3 position, 4 way valves under controller 31 provide alternating operation of a pair of pressure intensifiers. |
| X | X:1-5,11,12; Y:6-9 | GB2198081 A REXROTH See Figure 1. Electronic control of main piston reversing valve in twin cylinder arrangement |
| X | 1,5,7,11 | GB1450473 A CONSIGLO Pressure measuring transducer 7 feeds electronics 5 in controlling a reversing valve 4 in intensifier system with accumulator at output. |
| Y | 6-9 | EP1138872 A HALLIBURTON See Figure 1 and 2b. Bistable reversing valve controlling intensifier feeding accumulator. |

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$^{X}$ :

F1D

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

E21B; F04B; F15B

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

OPTICS, WPI, EPODOC, TXTE

**International Classification:**

| Subclass | Subgroup | Valid From |
|---|---|---|
| F15B | 0003/00 | 01/01/2006 |
| E21B | 0033/035 | 01/01/2006 |

| Subclass | Subgroup | Valid From |
|---|---|---|
| F04B | 0009/105 | 01/01/2006 |
| F04B | 0009/109 | 01/01/2006 |