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(54) **HYDRAULIC INTENSIFIERS**

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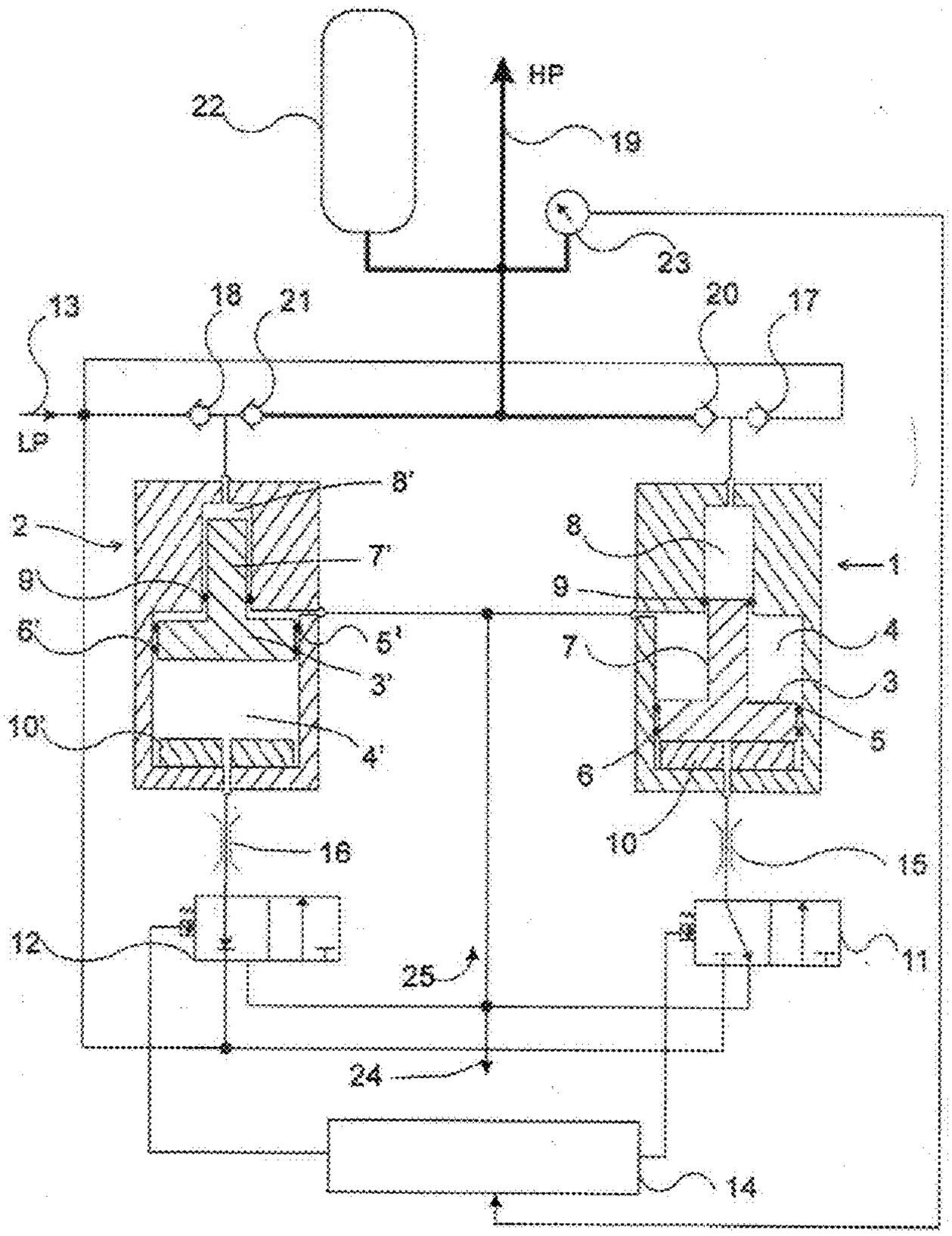
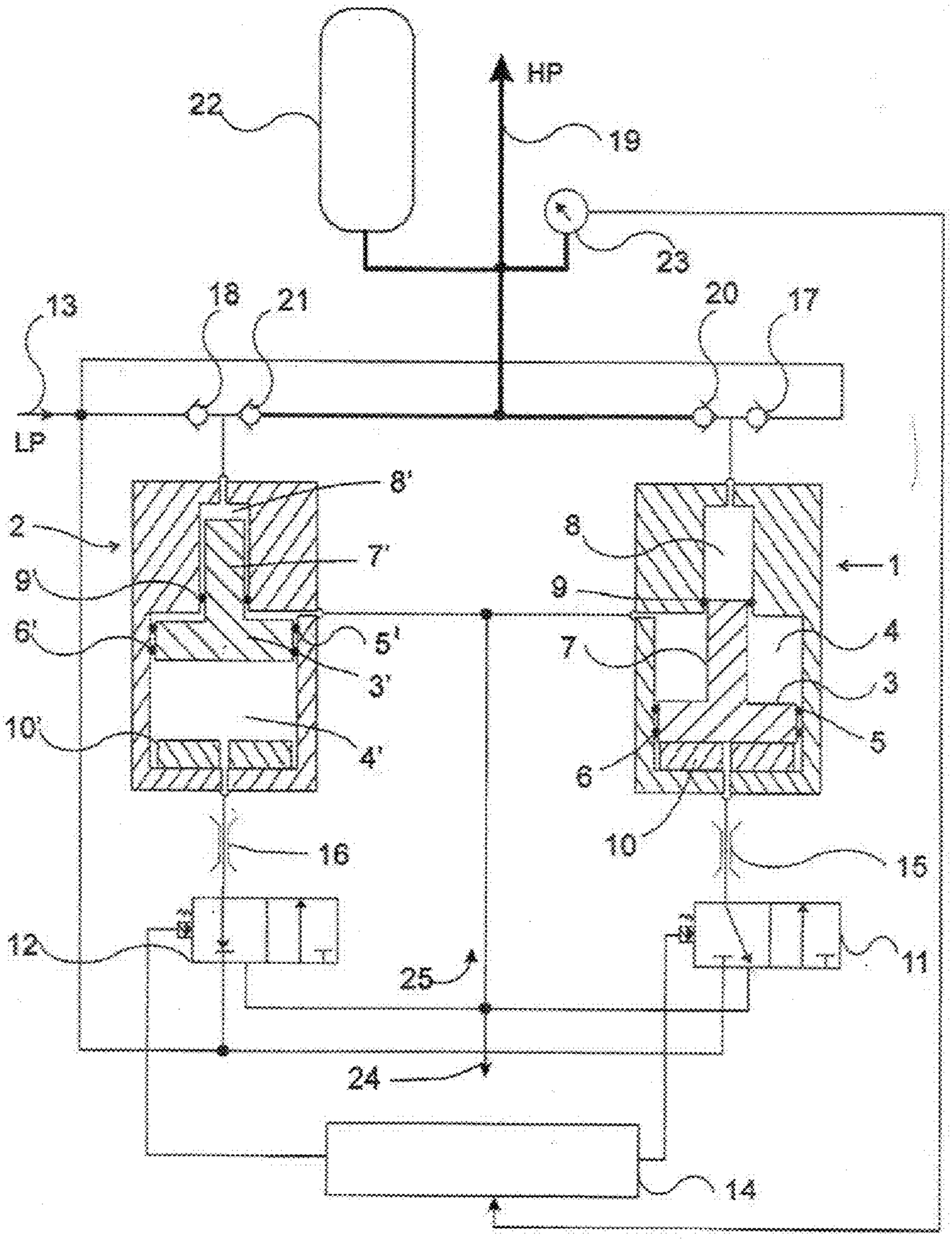
(57) **ABSTRACT**

A hydraulic intensifier with 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 first and second pistons are coupled together and the first piston has a larger cross-sectional area than the second piston. A high pressure output (**19**) is coupled to the chamber of the high pressure cylinder, there being; means (**13**) for supplying low pressure hydraulic fluid to the chamber of the low pressure cylinder; 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.

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# HYDRAULIC INTENSIFIERS

## CROSS REFERENCE TO RELATED APPLICATIONS

**[0001]** This Application relates claims priority to and the benefit of co-pending United Kingdom Patent Application No. 0811205.4 filed on 19 Jun. 2008, the full disclosure of which is hereby incorporated fay reference.

## BACKGROUND

**[0002]** 1. Field of Invention

**[0003]** The present invention relates to hydraulic intensifiers.

**[0004]** 2. Description of Related Art

**[0005]** Hydraulic intensifiers are devices that generate high hydraulic pressure from a low pressure source. When employed in subsea wells such as hydrocarbon production or injection wells, they 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.

**[0006]** 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.

**[0007]** 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.

## SUMMARY

**[0008]** Disclosed herein is a hydraulic intensifier having a piston and cylinder assembly with 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 an electronic device operatively connected to the directional control valve.

**[0009]** The hydraulic intensifier may further include a second piston and cylinder assembly, rite high pressure output being coupled to the chamber of the high pressure cylinder of the second piston and cylinder assembly; and a second 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 second piston and cylinder assembly, the electronic device connected to the directional control valves to supply low pressure fluid alternately to the chambers of the low pressure cylinders of the first and second piston and cylinder assemblies.

**[0010]** Another embodiment of a hydraulic intensifier includes 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 second piston and cylinder assembly, a high pressure output coupled to the chambers of the high pressure cylinders of the first and second piston and cylinder assemblies, a low pressure hydraulic fluid supply to the chambers of the low pressure cylinders of the first and second piston and cylinder assemblies, first and second electrically operated directional control valves in fluid communication with the supply of low pressure hydraulic fluid and the chambers of the low pressure cylinders of the first and second piston and cylinder assemblies respectively, and an electronic device operatively coupled to the directional control valves to selectively energize the control valves to thereby supply low pressure hydraulic fluid alternately to the chambers of said low pressure cylinders.

**[0011]** Low pressure hydraulic fluid could he supplied to the chambers of the high pressure cylinders via respective ones of first and/or 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.

**[0012]** The hydraulic intensifier could include a pressure sensing device 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. The electronic device could comprise a bistable device. A hydraulic accumulator can be optionally included that is coupled with the high pressure output.

**[0013]** A hydraulic intensifier could be one for use in a subsea well. In a subsea application electrical control could be provided via a subsea electronics module for a subsea well and/or the directional flow control could be provided by a directional control valve of a subsea control module for a subsea well.

**[0014]** Also disclosed herein is a method of producing high pressure hydraulic fluid. In one example the method includes 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, and controlling the supply of low pressure hydraulic fluid to the chamber of the low pressure cylinder by selectively energizing the directional control valve.

**[0015]** The method can also include providing a second piston and cylinder assembly, the high pressure output being coupled to the chamber of the high pressure cylinder of the second piston and cylinder assembly, providing a second directional control valve for controlling supply of low pressure fluid to the chamber of the low pressure cylinder of the second piston and cylinder assembly, and using an electronic device to selectively energize the directional control valves to supply low pressure fluid alternately to the chambers of the low pressure cylinders of the first and second piston and cylinder assemblies.

**[0016]** The present disclosure, in one example, 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.

## DESCRIPTION OF FIGURES

**[0017]** FIG. **1** schematically illustrates an example of a hydraulic intensifier in accordance with the present disclosure.

## DETAILED DESCRIPTION OF THE INVENTION

**[0018]** The method and system of the present disclosure will now be described more fully hereinafter with reference to the accompanying drawings in which embodiments are shown. The method and system of the present disclosure may be in many different forms and should not be construed as limited to the illustrated embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be through and complete, and will fully convey its scope to those skilled in the art. Like numbers refer to like elements throughout.

**[0019]** An example of a hydraulic intensifier for a subsea hydrocarbon extraction or injection well is provided in FIG. **1**. Two piston and cylinder assemblies **1** and **2**, which may be identical, are shown in sectioned view. An associated hydraulic circuit is shown schematically. Each piston assembly has a large cross-sectional area piston **3**, **3'** depending from one side and a smaller cross-sectional area piston **7**, **7'** depending from its opposite end. The larger cross-sectional area piston **3**, **3'** is shown disposed in the chamber **4**, **4'** of a low pressure cylinder. Seals **5**, **5'** and **6**, **6'** are shown between the piston **3**, **3'** and chamber **4**, **4'** of low pressure cylinder. The smaller cross-sectional area piston **7**, **7'** is shown in high pressure cylinder chamber **8**, **8'** with seal **9**, **9'** therebetween. The chamber **4**, **4'** of each low pressure cylinder includes a buffer **10**, **10'**; that can be manufactured from a resilient, hydraulic fluid resistant material, to minimise the impact of a fast-returning piston.

**[0020]** The operation of each of the piston assemblies **1** and **2**, may be controlled, alternately, by respective ones of standard solenoid-operated directional control valves (DCVs) **11** and **12**. A low pressure (LP) supply **13**, typically via the well umbilical, is shown providing hydraulic fluid to the DCVs **11** and **12**. The solenoids of the DCVs **11** and **12** are electrically energised alternately from a dc power source switched by an electronic device **14** such as a multivibrator, that can be bistable. Each DCV **11** and **12** is coupled to the chamber **4**, or **4'** of the respective low pressure cylinder via a respective restrictor **15** or **16**. Source **13** is shown connected to the chambers **8**, **8'** of the high pressure cylinders via check valves **17** and **18** respectively. Also, each of the chambers **8**, **8'** is shown connected to a high pressure (BP) 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.

**[0021]** An example of a 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, via check valves **17** and **18** respectively, a continuous supply of hydraulic fluid to the chambers **8**, **8'** of the high pressure cylinders. 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** may be controlled by an optional 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.

**[0022]** The piston **7'** in the piston/cylinder assembly **2** will be forced downwards, with the hydraulic fluid transferring from below the piston **3'** in the chamber **4'** to above the piston **3'** in the chamber **4'** via the DCV **12**. When de-energized, the DCV **12** directs flow received from the hydraulic restrictor **16** and along a path through the circuit as indicated by arrow **25**. 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 beneath to above the piston **3'** within the chamber **4'**, in the flow direction **25**, minimises the consumption of hydraulic fluid. Optionally, as the piston **3'** downstrokes, fluid in the chamber **4'** beneath the piston **3'** can be routed to chamber **8'**. Yet further optionally, as either of pistons **3**, **3'** is being urged upwards. fluid in die respective chamber **4**, **4'** above the piston **3**, **3'** being raised can be routed to the other chamber **4**, **4'** of the low pressure cylinder above the respective piston **3**, **3'**.

**[0023]** At a pre-set time, the electronic 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**. When energized, the DCV **12** directs low pressure fluid from the source **13** through the restrictor **16** and into the chamber **4'** below the piston **3'**. Although pressure in chambers **4'** and **8'** is

initially substantially the same, the larger surface area of piston **3'** creates an upward resultant force pushing the piston **7'** into the chamber **8'** to thereby form high pressure fluid in the piston/cylinder assembly **2**. The 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**.

**[0024]** In practice, the device **14** may be dispensed with in atypical 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.

**[0025]** 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.

**[0026]** 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.

**[0027]** 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.

**[0028]** The improvements described herein, therefore, are well adapted to carry out the objects and attain the ends and advantages mentioned, as well as others inherent therein. While presently preferred embodiments have been given for purposes of disclosure, numerous changes exist in the details of procedures for accomplishing the desired results. These and other similar modifications will readily suggest themselves to those skilled in the art, and are intended to be encompassed within the spirit of the present disclosure and the scope of the appended 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;

a low pressure hydraulic fluid supply in fluid communication with the chamber of the low pressure cylinder; and

an energizable directional control valve in selective fluid communication with the low pressure hydraulic fluid supply, in selective fluid communication with the chamber of the low pressure cylinder, and in selective fluid communication with the, so that when the directional control valve is energized the low pressure fluid supply and low pressure cylinder chamber are in fluid communication.

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

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

a second directional control valve having a side in fluid communication with the low pressure hydraulic fluid supply and a side in fluid communication with the chamber of die second low pressure cylinder, so that when the directional control valve is energized the low pressure fluid supply and the second low pressure cylinder chamber are in fluid communication.

**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 second piston and cylinder assembly;

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

means for supplying low pressure hydraulic fluid to the chambers of the low pressure cylinders of the first and second 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 second 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 claim **1**, 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 claim **3**, 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.

**7**. A hydraulic intensifier according to claim **1**, wherein said electronic means comprises a bistable device.

**8**. A hydraulic intensifier according to claim **3**, wherein said electronic means comprises a bistable device.

**9**. A hydraulic intensifier according to claim **1**, comprising a hydraulic accumulator coupled with said high pressure output.

**10**. A hydraulic intensifier according to claim **3**, comprising a hydraulic accumulator coupled with said high pressure output.

**11**. A hydraulic intensifier according to claim **1**, adapted for use in a subsea well.

**12**. A hydraulic intensifier according to claim **3**, adapted for use in a subsea well.

**13**. A hydraulic intensifier according to claim **1**, wherein said electronic means is provided via a subsea electronics module for a subsea well.

**14**. A hydraulic intensifier according to claim **3**, wherein said electronic means is provided via a subsea electronics module for a subsea well.

**15**. A hydraulic intensifier according to claim **11**, wherein the or each directional control value is provided by a directional control valve of a subsea control module for a subsea well.

**16**. A hydraulic intensifier according to claim **12**, wherein the or each directional control value is provided by a directional control valve of a subsea control module for a subsea well.

**17**. 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.

**18**. A method according to claim **17**, comprising:

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

providing a second such directional control valve for controlling supply of low pressure fluid to the chamber of the low pressure cylinder of the second 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 second piston and cylinder assemblies.

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