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(54) Title of the Invention: **Fluid injection apparatus and method**
Abstract Title: **Fluid injection apparatus and method**

(57) An apparatus for selectively injecting an additive fluid into a process fluid comprises an additive fluid supply line 13 having a pump 12. It also has an injection line 11 for delivering additive fluid to the process fluid, and a directional control valve 25 in the injection line operable between an open position in which it permits flow of the additive fluid in the injection line and a closed position in which it interrupts flow. The apparatus further includes a control means 18 for selecting a pulse rate for the directional control valve to control the flow rate of the additive fluid in the injection line. The pulse rate may be selected in response to a parameter of the additive, such as pressure or viscosity. The injector may be used to ensure that formation fluid flowing through a well is not inhibited by solidification of paraffin wax.

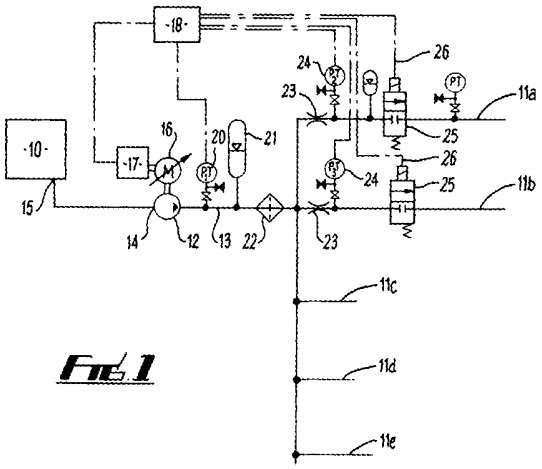

Fig 1

GB 2467792 A

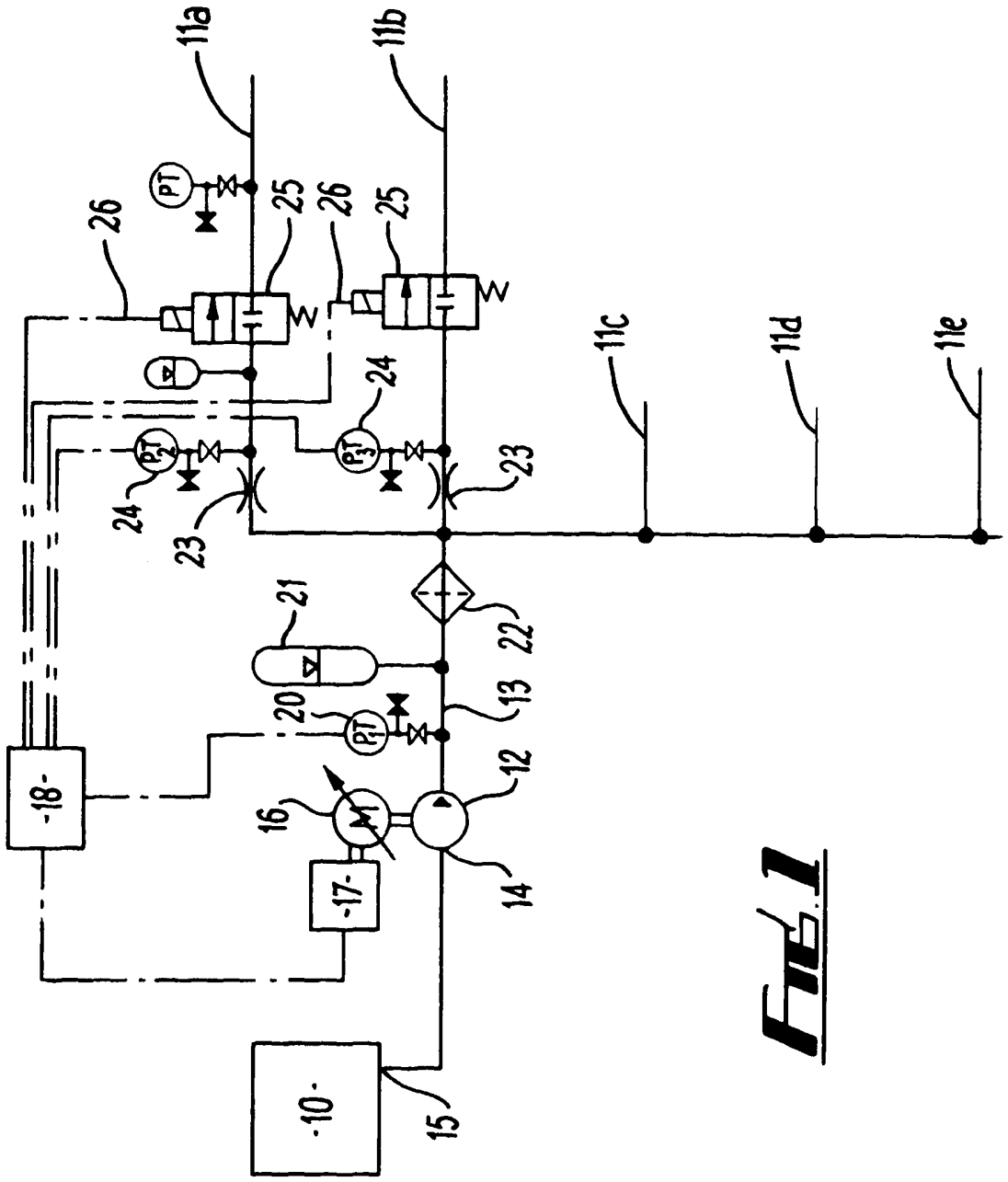

FIG.1

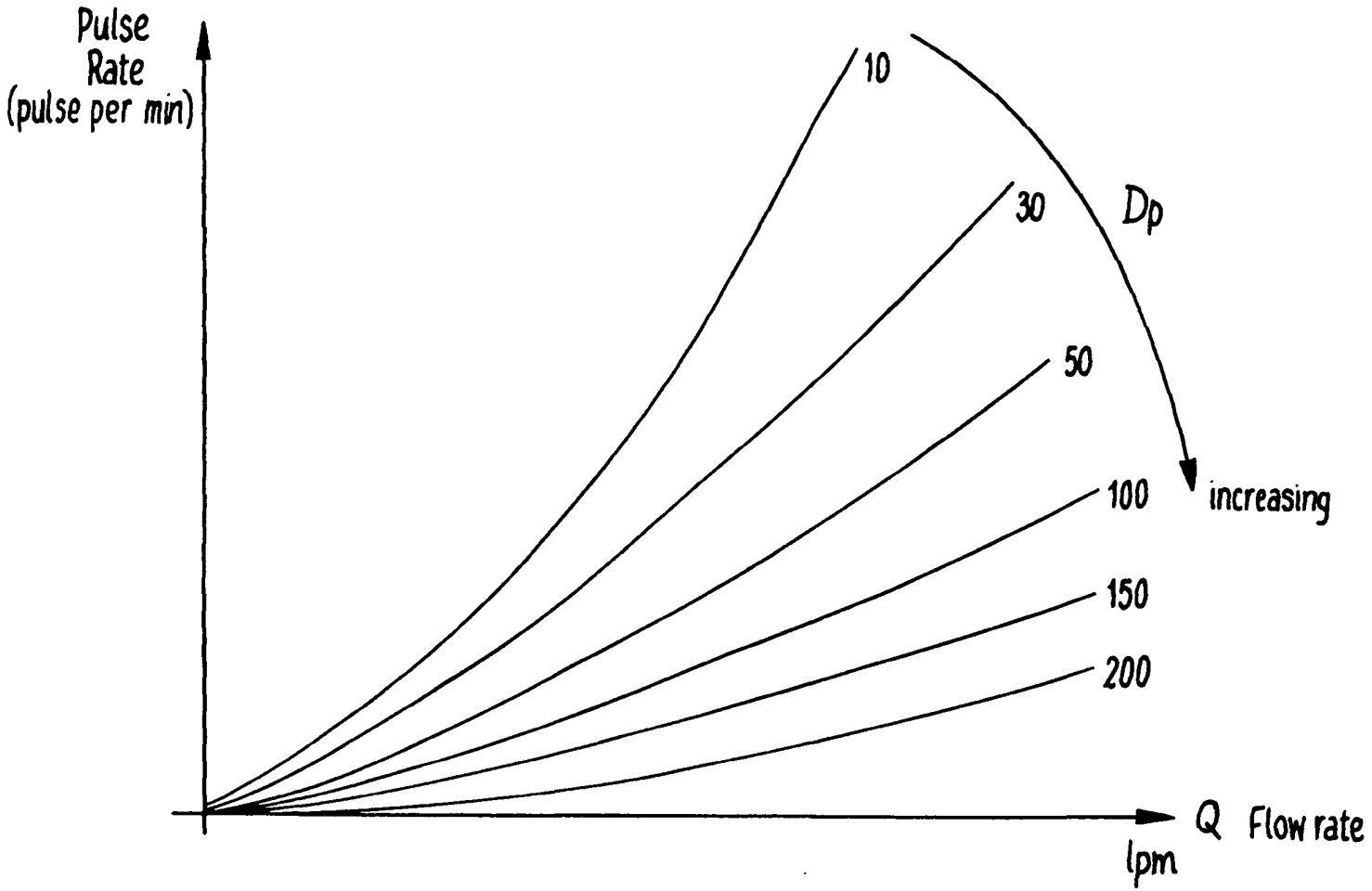
Pulse
Rate
(pulse per min)
10
30
50
100
150
200
Dp
increasing
Q Flow rate
lpm

FIG.2

FLUID INJECTION APPARATUS AND METHOD

The present invention relates to fluid injection apparatus and a method for selectively injecting an additive fluid into a process fluid.

In the oil, gas and petrochemical industries it is often necessary to treat the process fluid flowing through a well and/or pipeline with a chemical additive on a continuous or intermittent basis in order to ensure that the well continues to operate efficiently. For example, methanol or another suitable substance may be injected to inhibit the solidification of paraffin wax on the walls of the well or pipeline as this serves to restrict the process flow and may serve to inhibit the operation of valves within the pipeline. Other examples include hydrate, scale or corrosion inhibitors.

Injection of the chemical additive may be required at a variable rate depending on the flow conditions or pressure within the well or pipeline and a slow injection rate is often necessary to inhibit wax or hydrate formation.

In sub-sea applications the injection apparatus must be reliable as access for cleaning, repair or maintenance is difficult.

It is known to use a variable pump to control the chemical injection rate. One example of this is a hydraulically actuated diaphragm pump available from Milton Roy. Such a pump is typically operated by a controller or, alternatively, a solenoid and a plunger is displaced in a cylinder to displace hydraulic fluid on one side of a diaphragm. This serves to deflect the diaphragm which, in turn, displaces the chemical such that it is injected into the process flow.

In an alternative approach that is used in particular for slow flow rates, a pressure compensated flow valve injects the chemical at a consistent flow rate irrespective of upstream or downstream pressure changes. The variable inlet flow is incident on a first side of a piston and passes through a bleed path in the piston. The bleed path has an orifice so as to generate a pressure drop across the piston. The resultant force moves the piston against a biasing spring and a variable throttle, part of which is formed on the piston serves to maintain a constant outlet flow regardless of the inlet flow rate. In some applications it has been found that such valves are not particularly accurate. Moreover, they rely on delivering the chemical through small orifices or flow paths which have a tendency to become blocked by contaminants.

Since such valves are often situated sub sea it is a difficult process to get access to them for cleaning purposes. Multi-plate filter baffles have been employed to address this problem but these also have a tendency to become clogged with contaminants and restrict the flow.

It is an object of the present invention to obviate or mitigate the above, and other, disadvantages. It is also an object of the present invention to provide for improved, or alternative, fluid injection apparatus.

According a first aspect of the present invention there is provided fluid injection apparatus for selectively injecting an additive fluid into a process fluid at a given location comprising: an additive fluid supply line having a pump for pumping the additive fluid; at least one injection line for delivering additive fluid to the process fluid at the given location; a directional control valve in the injection line operable between an open position in which it permits flow of the additive fluid in the injection line and a closed position in which it interrupts the flow; a controller for sending a pulsed control signal at a selected pulse rate to the directional control valve to control the flow rate of the additive fluid in the injection line.

The apparatus of the present invention provides for a relatively simple, reliable and accurate way of modulating the flow rate of fluid. The pulse rate effectively controls the flow rate of the fluid in the injection line and can be used to deliver fluid accurately at a wide range of flow rates

The controller may be configured to vary the pulse rate in response to at least one parameter of the additive fluid which may be, for example, a detected pressure difference between the additive fluid in the supply line and the injection line. In order to determine the pressure difference a pressure sensor may be provided in the supply line and similarly a pressure sensor may be provided in the injection line. In each case the pressure sensors may transmit signals representative of the sensed pressure to the controller. In addition, or alternatively, the variation in pulse rate may be dependent on the viscosity of the fluid.

The pulsed control signal may be an electrical signal or, alternatively, it may be a pneumatic or hydraulic signal for a pilot inlet of the directional control valve. In the case of an electrical signal the directional control valve may be solenoid-operated.

The controller may be a programmable logic controller. It may store a look-up table in memory for determining the pulse rate based on the sensed pressure difference.

There may be a fluid additive fluid reservoir connected to the supply line. The pump may have an inlet in flow communication with an outlet of the reservoir.

The pump may be configured to maintain a constant supply line pressure and may be driven by a variable speed motor with an inverter drive. The inverter drive is preferably controlled by the controller.

There may be provided at least one fluid damper in the supply line and/or in the injection line.

There may be provided a plurality of injection lines each with its directional control valve. The directional control valves may be controlled so as to provide different flow rates in each of the injection lines.

According to a second method of the present invention there is provided a method for selectively injecting an additive fluid into a process fluid comprising: delivering an additive fluid from a supply line to at least one injection line for onward delivery to the process fluid; operating a directional control valve in the injection line in a pulsed manner between an open position to permits flow of the additive fluid in the injection line and a closed position in order to interrupts the flow; selecting a pulse rate for the directional control valve to control the flow rate of the additive fluid in the injection line.

The pulse rate is selected in response to at least one parameter of the additive fluid such as, for example, a pressure difference in the additive fluid between the supply line and injection line. Account may also be taken of other inherent fluid parameters such as, for example, viscosity.

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

Figure 1 is a schematic circuit diagram of a chemical injection control system in accordance with the present invention; and

Figure 2 is a graph showing exemplary solenoid calibration curves in the form of a plot of flow rate against solenoid control pulses per minute.

Referring now to figure 1, a chemical fluid additive for injection into a well, pipeline or the like is stored in a reservoir 10 and delivered to a plurality of injection lines 11a, 11b, 11c etc.. A hydraulic pump 12 delivers the fluid to a supply line 13 for onward transmission to the injection lines 11a, 11b, 11c etc. The pump 12 has an inlet 14 connected to an outlet 15 of the reservoir 10 and is driven by a variable speed motor 16 with an inverter drive 17 that is operated under the control of a programmable logic controller (PLC) 18.

The supply line 13 is fitted with a first pressure sensor 20 for determining the fluid pressure leaving the pump 12. The pressure reading is converted into an electrical signal that is transmitted to the PLC 18. Immediately downstream of the first pressure sensor 20 there is a damper accumulator 21 for damping significant pressure fluctuations in the fluid and a filter 22 for removing contaminants before the fluid is injected into the well or pipeline. The plurality of injection lines 11a, b, c are connected to a point downstream of the filter 22 and each such injection line has a calibrated fixed orifice 23, a second pressure sensor 24 and a directional control valve 25.

The second pressure sensor 24 operates in the same manner as the first sensor 20 and sends an electrical signal representative of the pressure in the respective injection line 11a, b, c, etc. to the PLC 18. Each fixed orifice 23 is calibrated accurately at a particular set point such that for a given pressure drop (determined by the difference in readings between the first and second pressure sensors 20, 24) across the orifice the flow rate through the orifice 23 is known.

Each of the directional control valves 25 is a solenoid-controlled, two-position, two-port, spring return valve with the operation of the solenoid being controlled by electrical signal sent from the PLC 18 along the line indicated by reference number 26. Each valve 25 is depicted in its normally closed position (to which it is biased by the return spring) where it blocks the respective injection line 11 a, b, c but is moved to the open position by the solenoid upon receipt of a control signal from the PLC 18. The signal delivered to the solenoid is pulsed so as to actuate the valve 25 between on and off positions. The pulse rate selected is dependent on the desired flow rate and the pressure drop (Dp) between the upstream supply line 13 and the downstream injection line 11a,b, or c etc. as determined from the pressure sensor

20, 23 readings. The PLC uses empirical data to modulate the pulse rate to achieve the desired flow rate in the injection line. This data is shown in the form of a graph in figure 2. The graph is effectively stored as a look-up table in a memory associated with the PLC 18. In figure 2 there is shown a number of plots of fluid flow rate Q in litres per minute (x axis) against the pulse rate (pulses per minute), each plot being for a different pressure drop (Dp) represented in bar. It will be appreciated that the graphs will vary for different viscosities of the chemical being injected.

It will be appreciated that any number of injection lines may be provided depending on the number of wells. Each line may be operated with a different flow rate. In the exemplary embodiment shown in figure 2 five injection lines 11a-11e are shown but any number may be provided. In the figure only the first and second injection lines 11a and 11b are shown with directional control valves 25 – the valves and other components being omitted from the subsequent injection lines 11c to 11e for clarity.

The upstream pressure is maintained substantially constant by the motor and inverter control.

The configuration allows a single upstream supply line 13 to be provided on shore or on a platform or floating vessel with the multiple injections lines 11a-e etc. being provided sub sea. Alternatively the injection lines may also be on shore or otherwise above the sea.

It is will be appreciated by one of ordinary skill in the art that the invention has been described by way of example only, and that the invention itself is defined by the claims. Numerous modifications and variations may be made to the exemplary design described above without departing from the scope of the invention as defined in the claims. For example, the solenoid of each directional control valve need not necessarily be controlled by pulsed electrical signals. In an alternative arrangement the solenoid is replaced by a piloting piston device that is provided with pulsed pressure signals (e.g. pneumatic) provided by a suitable controller. Furthermore, the data stored in the PLC 18 for determining the appropriate pulse rate may be other than empirical.

The described and illustrated embodiments are to be considered as illustrative and not restrictive in character, it being understood that only the preferred

embodiments have been shown and described and that all changes and modifications that come within the scope of the inventions as defined in the claims are desired to be protected. It should be understood that while the use of words such as "preferable", "preferably", "preferred" or "more preferred" in the description suggest that a feature so described may be desirable, it may nevertheless not be necessary and embodiments lacking such a feature may be contemplated as within the scope of the invention as defined in the appended claims. In relation to the claims, it is intended that when words such as "a," "an," "at least one," or "at least one portion" are used to preface a feature there is no intention to limit the claim to only one such feature unless specifically stated to the contrary in the claim. When the language "at least a portion" and/or "a portion" is used the item can include a portion and/or the entire item unless specifically stated to the contrary.

CLAIMS

1. Fluid injection apparatus for selectively injecting an additive fluid into a process fluid at a given location comprising:
an additive fluid supply line having a pump for pumping the additive fluid;
at least one injection line for delivering additive fluid to the process fluid at the given location;
a directional control valve in the injection line operable between an open position in which it permits flow of the additive fluid in the injection line and a closed position in which it interrupts the flow;
a controller for sending a pulsed control signal at a selected pulse rate to the directional control valve to control the flow rate of the additive fluid in the injection line.

2. Fluid injection apparatus according to claim 1, wherein the controller is configured to vary the pulse rate in response to at least one parameter of the additive fluid.

3. Fluid injection apparatus according to claim 2, wherein the at least one parameter is a detected pressure difference between the additive fluid in the supply line and the injection line.

4. Fluid injection apparatus according to claim 2, wherein the at least one parameter is the viscosity of the additive fluid.

5. Fluid injection apparatus according to any one of claims 1 to 4, wherein the pulsed control signal is an electrical signal.

6. Fluid injection apparatus according to claim 5, wherein the directional control valve is solenoid-operated.

7. Fluid injection apparatus according to any preceding claim, wherein the controller is a programmable logic controller.

8. Fluid injection apparatus according to any preceding claim, further comprising an additive fluid reservoir connected to the supply line.

9. Fluid injection apparatus according to any preceding claim, wherein the pump is configured to maintain a constant supply line pressure.

10. Fluid injection apparatus according to claim 9, wherein the pump is driven by a variable speed motor with an inverter drive.

11. Fluid injection apparatus according to claim 9, wherein the inverter drive is controlled by the controller.

12. Fluid injection apparatus according to any preceding claim, wherein there is provided at least one fluid damper in the supply line.

13. Fluid injection apparatus according to any preceding claim, wherein there is provided at least one fluid damper in the injection line.

14. Fluid injection apparatus according to any preceding claim, wherein there is provided at least one pressure sensor in the supply line or the injection line.

15. Fluid injection apparatus according to any preceding claim, wherein there is provided a plurality of injection lines each with a directional control valve.

16. A method for selectively injecting an additive fluid into a process fluid comprising:

delivering an additive fluid from a supply line to at least one injection line for onward delivery to the process fluid;

operating a directional control valve in the injection line in a pulsed manner between an open position to permit flow of the additive fluid in the injection line and a closed position in order to interrupt the flow;

selecting a pulse rate for the directional control valve to control the flow rate of the additive fluid in the injection line.

17. A method according to claim 15, wherein the pulse rate is selected in response to at least one parameter of the additive fluid.

18. A method according to claim 16, wherein the at least parameter is a pressure difference in the additive fluid between the supply line and injection line.

Application No:	GB0902585.9	**Examiner:**	Alan Jones
Claims searched:	1-18	**Date of search:**	28 May 2009

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, 5-14 & 16 at least	US5209300 A (AYRES) See e.g. figs, injection line 18, pulse consists of timer mechanism on valve 12 to control flow rate, col. 2 lines 7-21, col. 3 lines 18-24, col. 5 lines 51-60
X	1-18	WO2004/016904 A1 (BAKER HUGHES) See e.g. abstract, fig 4, apparatus 300, supply line 312a-m, pump 314a-m, sensors s3a-s3m & p12 lines 13-21, p14 lines 12-16
X	1-3, 5-14 & 16-18	US5517593 A (NENNIGER ET AL) See e.g. fig 4, fluid damper 113, bleed valve 116 & col. 9 lines 32-39, sensors 304

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

E21B; G01F

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

Online: WPI, EPODOC

International Classification:

Subclass	Subgroup	Valid From
E21B	0037/06	01/01/2006
G01F	0011/00	01/01/2006