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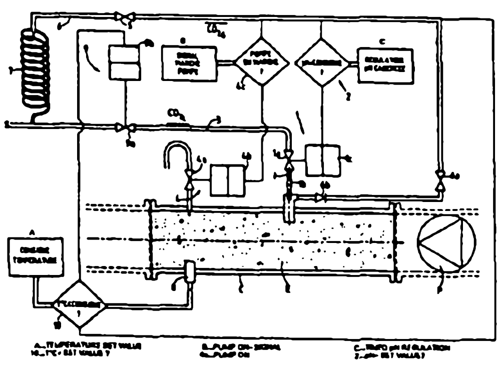

(57) Abstract

The invention concerns a novel method (and its associated device) for regulated injection of liquid carbon dioxide (CO_{2L}) in a pressurised liquid (L) inside a chamber. The invention is characterised in that said liquid carbon dioxide (CO_{2L}) is injected at a fixed timed flow rate protected by a gas stream (whenever the injection stops).

(57) Abrégé

La demanderesse propose un nouveau procédé (et son dispositif associé) d'injection régulée de dioxyde de carbone liquide (CO_{2L}) dans un liquide (L) sous pression à l'intérieur d'une enceinte. Ledit dioxyde de carbone liquide (CO_{2L}) est, selon celui-ci, injecté à un débit fixe, en mode cadencé, sous protection d'un flux gazeux (lors des arrêts d'injection).

Method and device for regulated injection of liquid carbon dioxide into a pressurized liquid

The subject of the present invention is a method and a device for the regulated injection of liquid carbon dioxide (CO_{2_L}) into a pressurized liquid. The regulation of the injection of CO_{2_L} is, according to the invention, the regulation of a fixed flow rate injected in stages.

The method and device of the invention are quite particularly suited to the injection of CO_{2_L} into a liquid flowing under pressure through a pipe.

The context of the present invention is that of the treatment with carbon dioxide (CO_2) of any type of liquid under pressure, particularly liquids consisting of reaction media, industrial effluent, drinking water, etc. Within the scope of the present invention, the applicant proposes an optimized technique for injecting liquid carbon dioxide (CO_{2_L}), which is optimized in particular both from the point of view of protecting the liquid into which the said CO_{2_L} is injected and from the point of view of protecting the environment.

In general, the injection of gaseous carbon dioxide (CO_{2_G}) is a perfectly mastered technique. However, implementation of the said technique assumes prior vaporization of the carbon dioxide stored in liquid state: $(CO_{2_L}) : \xrightarrow{vaporization} CO_{2_G}$. Such prior vaporization assumes the presence on the user site of a vaporizer, and entails a not insignificant power consumption. To be able to get around such prior vaporization is obviously very economically advantageous, both in terms of the savings made on investment (no vaporizer) and in terms of savings on operating costs (no power consumption).

The (direct) injection of CO_{2_L}, although therefore having a certain economic advantage, does, however, prove to be a technique which is more difficult to implement. Those skilled in the art are not unaware of this.

The applicant has already proposed a technique for the (direct) injection of CO_{2L}. This technique is described in Patent Application FR-A-2 641 854. It is relatively complicated, and its implementation entails significant investment. Its use is in fact, generally, justified only within large installations, if high flow rates of CO_{2L} are to be injected. The said technique involves, for injecting a variable flow rate of CO_{2L} (regulated, permanent and unstaged flow rate of CO_{2L}) injection which is regulated in proportional mode:

- a controlled valve, of the proportional (variable throughput) type, without an injector;
- an upstream pressure regulator for delivering the CO_{2L};

and is necessarily implemented with a CO_2 pressure between the said variable throughput valve and the said upstream pressure regulator which is greater than the pressure of the triple point of CO_2 (pressure higher than 5.2 bar).

The discussion of the background to the invention herein is included to explain the context of the invention. This is not to be taken as an admission that any of the material referred to was published, known or part of the common general knowledge in Australia as at the priority date of any of the claims.

The applicant wanted to develop another technique for the regulated injection of CO_{2L} into a liquid under pressure, which technique would in particular be easier to implement. It now proposes another such technique, which is particularly suited (although not strictly limited) to contexts in which the significant investment required to implement the technique according to FR-A-2 641 854 is no longer economically viable. According to the said other technique now claimed, the CO_{2L} is injected in stages (on or off) at a fixed flow rate. The regulation of the injection, according to the invention, is of a different type than in FR-A-2 641 854. In absolute terms, it may be considered as not being as good.

When implementing this type of injection of CO_{2L}, a regulated injection in stages, it needs to be capable, each time the injection of CO_{2L} is stopped, of avoiding:

- any of the pressurized liquid treated with the CO_{2L} from being drawn back up into the device used for injecting the CO_{2L} (as this is likely to lead to the injector becoming blocked with, for example, solid residues, contained in the said liquid); and

- any formation of a plug of water ice, particularly at the said CO_{2L} injection device (which is cold).

Faced with this technical problem inherent in implementing the regulated injection in stages of CO_{2L} into a liquid under pressure, the applicant recommends, each time the injection of the said CO_{2L} is stopped, the intervention of a gas. The said gas has the dual function of driving back the treated liquid, under pressure, and of protecting (isolating) the injection device (which thus remains operational) from the said treated liquid which is likely to freeze in situ.

According to the present invention, there is provided a method for the regulated injection of liquid carbon dioxide into a liquid under pressure inside a vessel, wherein:

- the said liquid carbon dioxide is injected in stages at a fixed flow rate by an injection device including an injection valve and an injection head tapped into a wall of the said vessel, the said injection head being positioned directly at the outlet of the said injection valve;

and :

- as soon as each injection of liquid carbon dioxide stops, a gas is delivered to the said liquid through the said injection head in place of the said liquid carbon dioxide; the said gas being delivered at a pressure which is high enough to prevent any of the said liquid being drawn back up inside the said injection head.

Also disclosed herein is a device for the regulated injection of liquid carbon dioxide into a liquid under pressure inside a vessel, said device including:

- an injection valve and an injection head tapped into a wall of the said vessel, the said injection head being positioned directly at the outlet of the said injection valve; the said injection valve being connected by a supply circuit to a convenient source of liquid carbon dioxide suitable for injection, in stages, at a fixed flow rate; and

- means for supplying the said injection head with a gas.

According to its first object, the invention therefore relates to an original method for the regulated injection of liquid carbon dioxide (CO_{2L}) into a liquid under pressure and more specifically to a method for the regulated injection, in stages, at a fixed flow rate, of CO_{2L} into a liquid under pressure which is implemented under the protection of a gas stream (when the said injection of CO_{2L} is stopped).

According to the said original method of the invention, the said CO_{2L} is injected into the liquid under pressure inside a vessel under the following conditions:

- it is injected in stages at a fixed flow rate by an injection device comprising an injection valve and an injection head tapped into a wall of the said vessel; the said injection head being positioned directly at the outlet of the said injection valve;
- as soon as each injection thereof is stopped, a gas is substituted for it: as soon as each injection of liquid carbon dioxide (CO_{2L}) is stopped, a gas is delivered to the said liquid through the said injection

head in place of the said liquid carbon dioxide (CO_{2_L}); the said gas being delivered at a pressure which is high enough to prevent any of the said liquid from being drawn back up inside the said injection head.

The injection of CO_{2_L}, according to the method of the invention, is a true injection, a direct injection into the liquid to be treated, through a wall of the vessel containing the said liquid under pressure. To implement it, the said injection involves an appropriate injection device which comprises an injection valve and an injection head. The said injection valve comprises a valve, for example of the ball valve type, associated with an injector. The said injector is built into the structure of the said valve to a greater or lesser extent. For injection to work correctly, the person skilled in the art will readily understand that, on the one hand, the injector must not be truly separate from the valve and, on the other hand, that the injection head needs to be positioned directly at the outlet of the injection valve.

The regulated injection according to the invention is, as already stated, of the type involving the injection of a preset fixed flow rate in stages. The injection valve is either on or off.

As soon as the said valve is closed, and CO_{2_L} is no longer injected, and this is a characteristic of the invention, a gas becomes involved. It becomes involved at the injection head (downstream of the injection valve) in place of the said CO_{2_L}, to be delivered into the liquid under pressure. It will be readily understood that, according to an advantageous alternative form, the said injection head has at least two inlets:

- one for the CO_{2_L},
- one for the protective gas;

and one outlet for alternately delivering the said CO_{2_L} and the said protective gas, into the pressurized liquid.

The said gas, in order to play its part as a gas that protects the injection device from the pressurized liquid, is obviously used at sufficient pressure.

The said protective gas (affording, in particular, thermal protection against the CO_{2_L} which is injected at about -80°C) which is involved, characteristically, in the injecting, according to the invention, of CO_{2_L} in stages into a pressurized liquid may, in particular, consist of an "inert" gas which is inert with respect to the said liquid and "compatible" with the said liquid and incapable of affecting it, of giving rise to chemical reactions within it ("inert" here is meant at least in relative terms). This may in particular be a gas which is inert in the chemical meaning of the word ("inert" then used in absolute terms), or an inert gas such as nitrogen (N_2).

However, the scope of the invention does not preclude the use, by way of a protective gas, of some other type of gas, a non-inert gas. Thus, according to a particularly preferred alternative form, the said protective gas is not an inert gas but consists of carbon dioxide: CO_{2_G}. In the context of this alternative form, the pressurized liquid therefore receives, in alternation, CO_{2_L} and CO_{2_G}. The said CO_{2_G} may come from any appropriate source. Advantageously, it is the result of the vaporizing of a fraction of CO_{2_L} tapped from the CO_{2_L} supply circuit of the injection device upstream of the said injection device. A single CO_{2_L} supply source is then needed for implementing this advantageous alternative form of the method of the invention. The use of some other non-inert gas may also be consciously chosen; the said gas then, in addition to performing its primary function of a protective gas, also then performing at least one other function.

Irrespective of the nature of the gas delivered (inert gas, CO_{2_G}, other gas) when injection of the CO_{2_L}

into the pressurized liquid is stopped, it may be a good idea to remove the said gas, at least in part, from the said liquid. Such removal cannot be prejudicial, if performed carefully, in that the said gas, simply by being delivered into the liquid, has fulfilled its function of securing the injection of CO_{2_L}. By contrast, in certain contexts, it may prove to be highly opportune if not almost compulsory. In particular, it may thus be possible to avoid the creation of sizable layers or pockets of gas in the vessel containing the pressurized liquid.

If the said vessel consists of a pipe within which the said pressurized liquid flows, under the action of a pump, the person skilled in the art will readily understand that such pockets of gas are likely to cause the pump to become unprimed. In order to constantly maintain a head of liquid downstream of the said pump, it is therefore strongly recommended when implementing the method of the invention that the gas delivered into the liquid be removed at an opportune moment (when the said pump is stopped).

In general, the protective gas delivered, during stoppages in the injection of CO_{2_L}, is therefore advantageously removed, at least in part. The gas thus collected may advantageously be recycled (by way of protective gas).

According to the method of the invention, the injection of CO_{2_L}:

- at a fixed flow rate, in stages,
- under the protection of a gas stream,

is generally performed under the following conditions: the CO_{2_L} is injected at an upstream pressure of between about 14×10^5 and 20×10^5 Pa (14 and 20 bar) and at an upstream temperature of between -20°C and -30°C.

Advantageously, for obvious safety reasons, the said injection of CO_{2_L} is performed with the temperature of the liquid into which the said CO_{2_L} is injected monitored; the injection of the said CO_{2_L}

being stopped as soon as the temperature of the liquid is below a set point temperature. Specifically, it is appropriate to be able, at any moment, to avoid the consequences of an abnormal duration of injection of CO_{2L} (particularly one inherent to equipment failures: injection valve failure for example), at any moment to avoid a dangerous drop in the temperature of the liquid which may lead to the chamber containing the said liquid freezing solid.

The method of the invention, as described hereinabove in general terms and hereinbelow in greater detail with reference to the single appended figure can be implemented in various contexts. As already mentioned, it is particularly suited to the regulated injection, in stages, of CO_{2L} into a liquid flowing under pressure in a pipe. Such a liquid may flow up to pressures of 8-10 bar. It generally flows at pressures of 4-5 bar. In any event, the applicant has been able to verify the feasibility and advantages of its new reliable method for injecting CO_{2L} into liquids flowing at such pressures.

The liquids "treated with CO_{2L} according to the invention" may consist of all kinds of liquids: they may in particular be reaction media, industrial effluent, drinking water, etc.

They may be treated with CO_{2L} for various purposes, particularly for the purposes of descaling and/or preventing the build-up of scale in the devices which contain them or within which they flow.

The method of the invention is also quite particularly suited to lowering and advantageously controlling the pH of industrial effluent before discharging it into a drain. In this context, the injection of CO_{2L} is advantageously directly slaved to the measurement of the pH.

We now propose to describe, in general terms, the second aspect of the present invention, namely a device for the regulated injection of liquid carbon dioxide (CO_{2_L}) into a liquid under pressure inside a vessel; the device being suited to the implementation of the method that was the first object of the present invention.

The said device comprises:

- an injection valve and an injection head tapped into a wall of the said vessel, the said injection head being positioned directly at the outlet of the said injection valve; the said injection valve being connected by a supply circuit to a convenient source of liquid carbon dioxide (CO_{2_L}) suitable for injection, in stages, at a fixed flow rate; and
- means for supplying the said injection head with a gas.

It in fact comprises appropriate means for implementing an injection of CO_{2_L} at a fixed flow rate in stages; the means being arranged to allow the protective gas to be delivered each time the said injection of CO_{2_L} is stopped. The said appropriate means comprise the injection valve (valve plus injector or valve incorporating the said injector) and an injection head. In an original manner, the said injection head is, according to the invention, capable of being supplied alternately with CO_{2_L} and with gas for delivering the said CO_{2_L} and the said gas into the pressurized liquid. Advantageously, as already mentioned, the said injection head comprises at least two inlets and one outlet. Particularly advantageously it comprises, facing the injector, a first inlet for the CO_{2_L}, facing the said first inlet a (direct) outlet into the liquid and, arranged at 90° to its axis connecting the said first inlet and the said outlet, a second inlet for the gas.

The injection head of the injection device according to the invention is therefore connected, on the one hand, to a suitable source of CO_{2_L} and, on the other hand, to a suitable source of protective gas.

Given that it has been seen that the said protective gas may consist of CO_{2_G} and that advantageously the said CO_{2_G} results from the vaporization of a fraction of CO_{2_L} tapped from the CO_{2_L} supply circuit of the injection valve, it will be understood that according to an advantageous alternative form, the device of the invention comprises, arranged on the said CO_{2_L} supply circuit, upstream of the injection valve, means for tapping and vaporizing a fraction of the said CO_{2_L}; the said tapping and vaporizing means being connected to the means for supplying the injection head with gas. The secured device for injecting CO_{2_L} according to the invention can therefore operate connected to a single source of CO_{2_L}.

The said device comprises the essential means specified hereinabove, obviously associated with appropriate control means. The said essential means are also advantageously associated:

- with means for removing the gas delivered to the liquid and, according to a particularly advantageous alternative form, with means of recycling the said removed gas recovered. In the particular context in which the injection head of the injection device according to the invention is tapped into the wall of a pipe within which the liquid flows under pressure, under the action of means (such as pumps) of causing the said liquid to flow under pressure, the said means of removing the gas delivered to the said pipe are obviously arranged downstream of the said injection head and are advantageously slaved to the said means of causing the said liquid to flow under pressure so that removal of the said gas is performed with no effect on the causing of the said liquid to flow. In any event, it is within the competence of the person skilled in the art to design such means of removing the gas delivered to the vessel and to possibly coupling the said removal means to means for recycling the said delivered gas recovered;

- with a device for controlling the temperature of the liquid into which the CO_{2_L} is injected. The intervention of such a controlling device is opportune, for obvious safety reasons. This controlling device advantageously comprises means of measuring the temperature of the "treated" liquid and means for stopping the injection of CO_{2_L}; which means are to be actuated when the said temperature is below a set point temperature. It will be appreciated that, particularly advantageously, the said device also comprises means for automatically slaving the said means of stopping the injection of CO_{2_L}, which slaving means automatically activate the said stopping means as soon as the measured temperature is below a set point value. With or without the intervention of such slaving means (and advantageously with), it is strongly recommended that the means of stopping the injection of CO_{2_L} comprises a valve known as a safety valve, mounted on the CO_{2_L} supply circuit upstream of the CO_{2_L} injection valve. This then provides a device for controlling the temperature which, independently of the regulation (because the safety valve or shut-off valve is upstream of the injection valve) provides the installation with positive temperature protection.

From its method and device aspects the present invention is now described with reference to the single appended figure. The said figure schematically depicts a device of the invention suitable for implementing an advantageous alternative form of the method of the invention.

Liquid carbon dioxide (CO_{2_L}) from a source S is injected according to the invention (under the protection of a gaseous stream of carbon dioxide (CO_{2_G}) when injection is stopped) into a liquid effluent L made to flow under pressure by means of the pump P through the pipe C. The said injection of CO_{2_L}, at a fixed flow rate, is regulated so that it is injected in stages.

It is performed, slaved to automatic slaving means 2, to regulate the pH of the said liquid effluent L.

The means 1 of injecting said CO_{2_L} into the liquid effluent L consist mainly of an injection valve 1a of the ball valve type, connected directly to an injection head 1b tapped into the pipe C. The said valve 1a is fitted with an injector i on the injection head 1b side. The said injection valve 1a operates either on or off, it is either open or closed. Its opening and its closure are controlled by the actuator 1c, slaved to the automatic slaving means 2. The said actuator 1c, installed some distance away in a temperate region, is supplied with gas via the CO_{2_G} supply circuit, to cause it to work.

The said valve 1a is open when the pH of the liquid effluent L is higher that a preset set point value; it is closed by the actuator 1c when the said pH remains below or equal to the said set point value. The said valve 1a is supplied with CO_{2_L} via the supply circuit 3 connected to the source S.

The injection head 1b tapped into the pipe C makes it possible, alternately, to deliver CO_{2_L} and CO_{2_G} to the liquid effluent L. It comprises:

- facing the injector i of the valve 1a, a first inlet for the CO_{2_L};
- facing the said first inlet, an outlet (into the liquid effluent L),
- and, arranged at 90° to its axis connecting the said first inlet and the said outlet, a second inlet for the CO_{2_G}.

A line 6 for carbon dioxide in the gaseous state (CO_{2_G}) provides a constant supply to this second inlet via , in this order, a coil 7, an expansion valve 5, a flow regulating valve 6a and, finally, a nonreturn valve 6b. In the context of the alternative form depicted, the protective gas used is therefore carbon dioxide which has been tapped from the liquid carbon dioxide supply circuit 3. The fraction of CO_{2_L} tapped off heats up and vaporizes in the said coil 7 at ambient temperature. It is then expanded by the pressure-reducer 5 before being injected via the flow regulating valve 6a, the nonreturn valve 6b and the injection head 1b.

The pipe C is equipped, downstream of the injection head 1b, with means 4 for removing the CO_{2_G} injected. The said removal means 4 comprise:

- a vent valve 4a,
- an actuator 4b which controls the closing of the said valve 4a, via automatic slaving means 4c.
- the said vent valve 4a is normally open when no voltage is applied (always open). Thus, in the event of a power supply failure, it automatically allows the protective CO_{2_G} to escape. It closes under the action of the actuator 4b as soon as the pump P that transfers the liquid effluent L is running. By contrast, as soon as the said pump P stops, the said valve 4a opens, thus venting the injected CO_{2_G} to the air, avoiding the formation of pockets of gas downstream of the injection. This valve 4a therefore makes it possible always to maintain a head of liquid downstream of the pump P. Any re-starting of the pump P will be able to take place without the risk of the pump becoming unprimed.

The device depicted also comprises a unit for monitoring the temperature of the liquid effluent L. What happens is that if the duration for which the CO_{2_L} is injected is extended abnormally (for example in the event of a failure of the pH-meter, a failure of the pH regulator, a failure of the injection valve 1a), the temperature of the said liquid effluent L may drop to dangerous levels, until the pipe C freezes solid.

The said temperature monitoring unit comprises:

- a temperature probe 8 measuring the temperature of the said liquid effluent L;

- a device for controlling this temperature, which itself comprises automatic slaving means 10 and a valve actuator 9b;

- a valve known as a safety valve 9a, controlled by the said actuator 9b, arranged on the CO_{2_L} supply circuit 3 and allowing the CO_{2_L} supply to be shut off.

The said valve 9a and its actuator 9b constitute the means 9 of stopping the said CO_{2_L} supply.

This monitoring unit provides positive temperature protection independent of the regulation of the pH because the safety valve 9a (or shut-off valve) is upstream of the injection valve 1a. It may also be noted that the said safety valve 9a is obviously downstream of the point at which the fraction of CO_{2_L} intended, according to the invention, to generate, in the coil 7, the CO_{2_G} used in regulation is tapped off.

Between the said safety valve 9a and the injection valve 1a there is a safety release valve 11.

It will also be noted that the actuators involved (actuators 1c, 4b and 9b for, respectively, the injection valve 1a, the vent valve 4a and the safety valve 9a) are pneumatic actuators supplied with gas (CO_{2_G}) tapped from the supply circuit 6 of the injection head 1b.

Upon studying the said figure and the above description, the person skilled in the art will have grasped the entire benefit of the present invention which proposes the injection of CO_{2_L} in stages at a fixed flow rate under the protection of a stream of CO_{2_G} when the injection is stopped. Specifically:

- when injecting the CO_{2_L} into the liquid effluent L, the supply of CO_{2_G} is automatically interrupted thanks to the pressure differential;

- by contrast, as soon as the said injection of CO_{2_L} stops, the supply of CO_{2_G} is instantly resumed with a set minimum flow rate, thus thermally isolating the downstream of the injection zone (which is at about -80°C) from the liquid effluent L (which is itself at a positive temperature).

The following are advantageously associated with the means needed to implement the said injection of CO_{2_L} under the protection of CO_{2_G}:

- a subassembly for venting the gaseous stream of CO_{2_G} to the air;
- a subassembly for controlling the temperature of the liquid effluent.

The present invention is finally illustrated by the following example.

An installation of the kind depicted schematically in the appended figure is used under the conditions below.

The liquid industrial effluent "to be treated" is transferred at variable flow rate (from 30 to 50 m^3/h) by means of a pump at 2.5 bar from an upstream tank to a downstream tank which empties into the drain. The said effluent cannot, however, be discharged into the said drain unless its average pH is 8 at most.

A stainless steel sleeve with a nominal diameter of 125 mm, equipped with an injection valve (ball valve plus injector at the valve outlet) and an injection head is placed (tapped into the pipe) just after the transfer pump so that the CO_{2_L} injected/effluent treated contact time is as long as possible between the two tanks.

The injection valve is equipped with a 0.9 mm injector which provides a flow rate of 12g of CO_{2_L} per s.

The flow rate of gas affording protection to the injection head (CO_{2_G} tapped from the CO_{2_L} supply circuit) has been adjusted to a minimum value of about 3 l/min.

As soon as the measurement of the pH shows an effluent pH higher than 8, CO_{2_L} is injected for a duration of the order of 6 s out of a fixed cycle of 8 s. The duration of the injection decreases thereafter until it becomes zero by virtue of the PID loop (which provides proportional integral derivative control).

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. Method for the regulated injection of liquid carbon dioxide into a liquid under pressure inside a vessel, wherein:

- the said liquid carbon dioxide is injected in stages at a fixed flow rate by an injection device including an injection valve and an injection head tapped into a wall of the said vessel, the said injection head being positioned directly at the outlet of the said injection valve;

and :

- as soon as each injection of liquid carbon dioxide stops, a gas is delivered to the said liquid through the said injection head in place of the said liquid carbon dioxide; the said gas being delivered at a pressure which is high enough to prevent any of the said liquid being drawn back up inside the said injection head.

2. Method according to Claim 1, wherein the said gas delivered is carbon dioxide; the said carbon dioxide advantageously resulting from the vaporizing of a fraction of liquid carbon dioxide tapped from the liquid carbon dioxide supply circuit upstream of the said injection device.

3. Method according to any one of Claims 1 and 2, wherein the said gas delivered to the said liquid is, at least in part, removed and advantageously recycled.

4. Method according to any one of Claims 1 to 3, wherein the said liquid carbon dioxide is injected at an upstream pressure of between about 14×10^5 and 20×10^5 Pa (14 and 20 bar) and at an upstream temperature of between -20°C and -30°C.

5. Method according to any one of Claims 1 to 4, wherein it is carried out with the temperature of the said liquid being controlled;

the injection of liquid carbon dioxide being stopped as soon as the temperature of said liquid drops below a set point temperature.

6. Method according to any one of Claims 1 to 5, wherein it is implemented for the regulated injection, in stages, of liquid carbon dioxide into a liquid flowing under pressure through a pipe; the gas delivered to the said liquid as soon as each injection of liquid carbon dioxide stops being advantageously, at least in part, removed when the said liquid stops circulating.

7. Method according to any one of Claims 1 to 6, wherein the said liquid carbon dioxide is injected for descaling purposes and/or for the purposes of preventing the build-up of scale.

8. A method according to claim 1, substantially as herein described with reference to the accompanying drawing.

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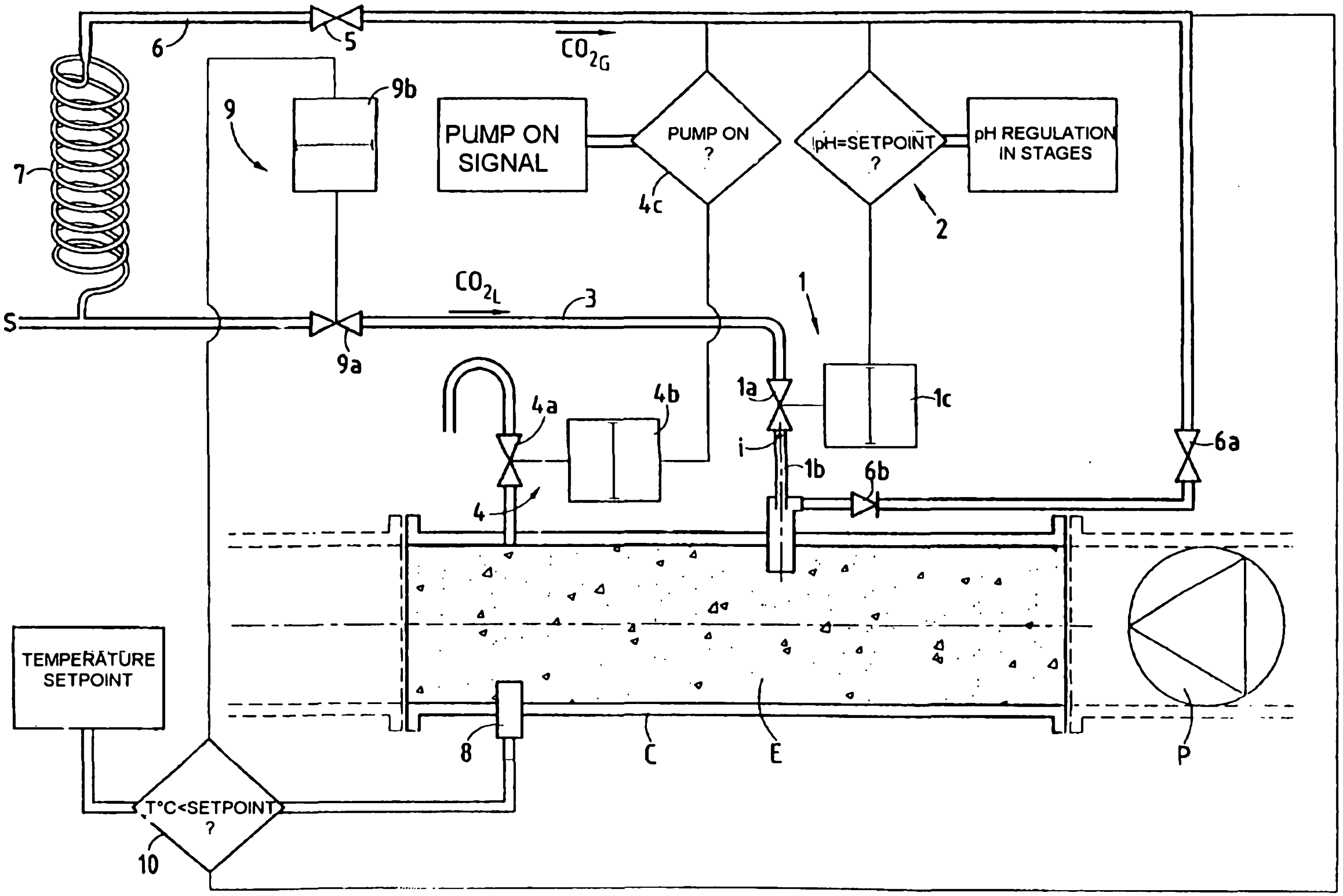

6
5
CO_{2G}
9b
9
PUMP ON SIGNAL
PUMP ON ?
pH=SETPOINT ?
pH REGULATION IN STAGES
7
4c
2
1
CO_{2L}
3
S
9a
4a
4b
1a
1c
i
1b
6b
6a
4
TEMPERATURE SETPOINT
T°C<SETPOINT ?
10
8
C
E
P