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(54) **METHOD FOR OPERATING AN INSTALLATION FOR THE GEOLOGICAL SEQUESTRATION OF CARBON DIOXIDE IN AN AQUIFER RESERVOIR**

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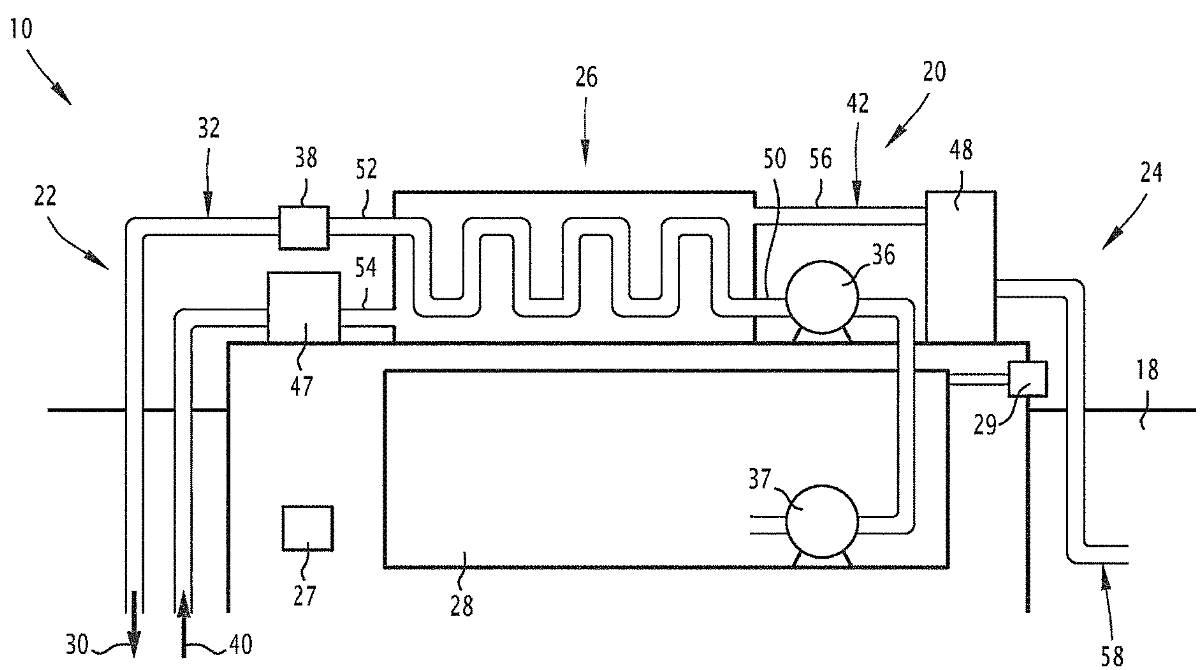
(57) **ABSTRACT**

A method for operating an installation for the geological sequestration of carbon dioxide, comprising: a structure; a device for injecting a flow of carbon dioxide into a geological reservoir, the injection device comprising an injection pipe; and a device for extracting a flow of water from the geological reservoir, the extraction device comprising an extraction pipe. The installation further comprises a heat exchanger, which is connected to the injection and extraction pipes; and the method comprises the following steps: injecting the flow of carbon dioxide into the reservoir, simultaneously extracting the flow of water from the reservoir; and bringing the flows of carbon dioxide and of water into thermal contact in the exchanger.



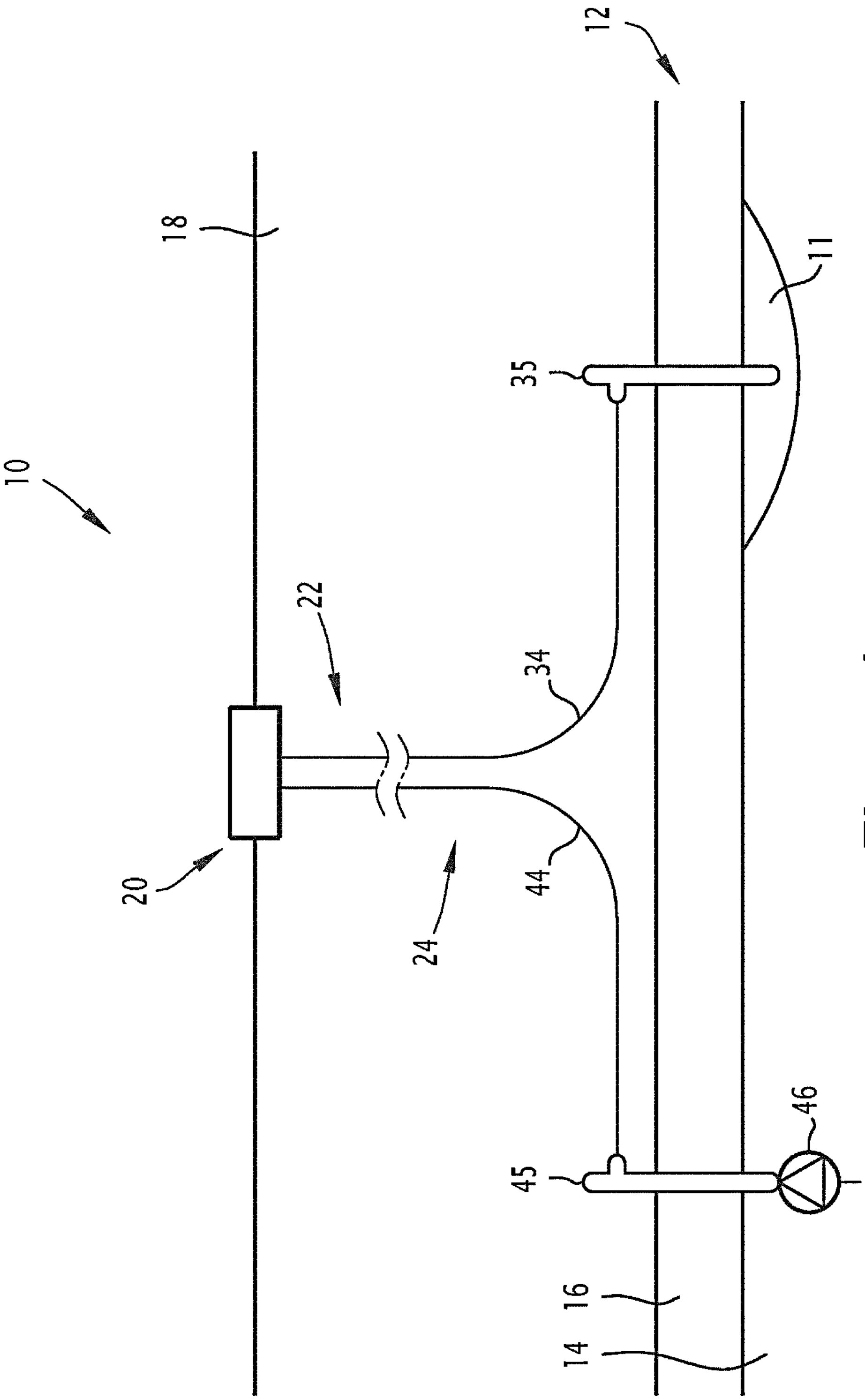


Figure 1

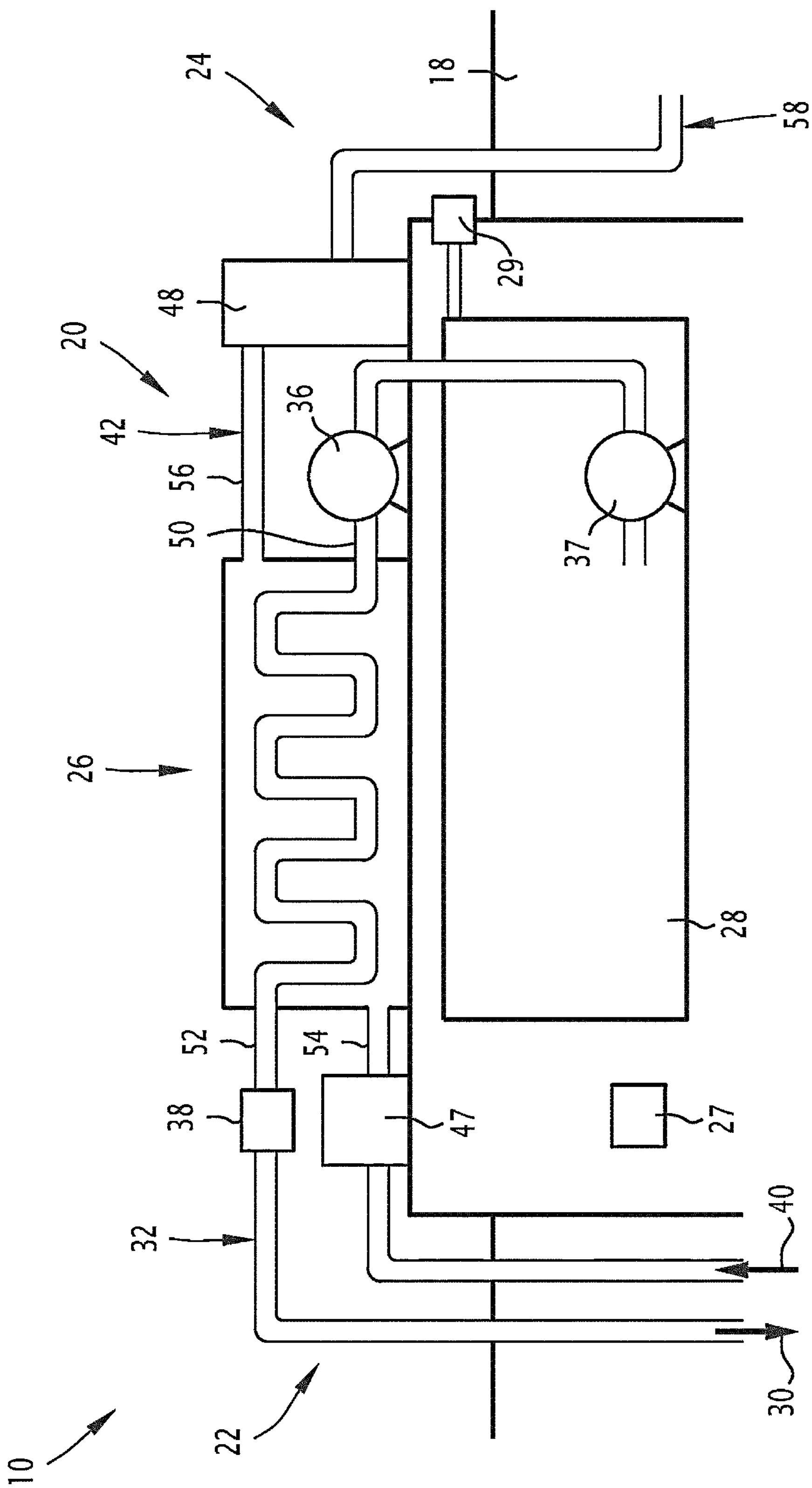


Figure 2

METHOD FOR OPERATING AN INSTALLATION FOR THE GEOLOGICAL SEQUESTRATION OF CARBON DIOXIDE IN AN AQUIFER RESERVOIR

[0001] The present invention relates to a method for operating an installation for the geological sequestration of carbon dioxide, said installation comprising: a structure, preferably floating; an injection device, suitable for injecting a flow of carbon dioxide into a geological reservoir from the structure, said injection device comprising an injection pipe intended to receive said flow of carbon dioxide upstream of the geological reservoir; and an extraction device, suitable for extracting a flow of water from said geological reservoir, said extraction device comprising an extraction pipe intended to receive said flow of liquid water downstream of the geological reservoir.

[0002] The invention is particularly applicable to off-shore installations, as described in US2017/0283014, or in the as yet unpublished application FR2107559 to the Applicant. These installations are designed to inject carbon dioxide (CO_2) into geological reservoirs, particularly underwater ones, for sequestration purposes.

[0003] Carbon dioxide sequestration aims to reduce greenhouse gas emissions into the atmosphere. In particular, carbon dioxide has been known to be injected into aquifer reservoirs, that is sites with an underground water supply. The paper "*IEAGHG Investigation of Extraction of Formation Water from CO_2 Storage*", *Energy Procedia* 37 (2013) 2479-2486, illustrates the benefits of extracting water from the reservoir simultaneously with carbon dioxide injection. These advantages include a reduction in pressure inside the reservoir, which facilitates carbon dioxide injection.

[0004] Before injection, it is common practice to store carbon dioxide in liquid form, at temperatures below −20° C. Such temperatures are too low for injection, as they entail the risk of hydrate formation in the reservoir's diffusion channels, and/or blockage of said channels. Before injection, it is best to raise the temperature of the carbon dioxide, for example to between 0° C. and 5° C.

[0005] Furthermore, the water extracted from aquifer reservoirs is often at a high temperature, for example between 50° C. and 65° C. The extracted water is discharged into the sea, for example. To comply with environmental standards, water must be treated before being discharged, in particular by lowering its temperature.

[0006] The purpose of the present invention is to provide an improved method for injecting carbon dioxide into an aquifer reservoir with simultaneous extraction of water from said reservoir.

[0007] To this end, the invention has as its object an operating method of the aforesaid type, wherein: the installation further comprises a heat exchanger, which is connected to the injection and extraction pipes; and the method comprises the following steps: injecting the flow of carbon dioxide into the reservoir, simultaneously extracting the flow of water from said geological reservoir; and bringing the flow of carbon dioxide upstream of the geological reservoir into thermal contact, within the heat exchanger, with the flow of water extracted from said geological reservoir.

[0008] According to other advantageous aspects of the invention, the operating method comprises one or more of the following features, taken individually or in any technically possible combination:

[0009] the structure comprises a compartment for storing carbon dioxide in a liquid state; and the flow of carbon dioxide into the geological reservoir is injected from said storage compartment;

[0010] carbon dioxide is injected continuously into the geological reservoir;

[0011] when the flow of carbon dioxide is brought into thermal contact with the extracted flow of water, said flows circulate in counter-current in the heat exchanger;

[0012] when the flow of carbon dioxide is brought into thermal contact with the extracted flow of water, each of said flows is in the liquid phase.

[0013] The invention further relates to an installation for the geological sequestration of carbon dioxide, said installation comprising: a structure, preferably floating; an injection device, suitable for injecting a flow of carbon dioxide into a geological reservoir from the structure, said injection device comprising an injection pipe intended to receive said flow of carbon dioxide upstream of the geological reservoir; and an extraction device, suitable for extracting a flow of water from said geological reservoir, said extraction device comprising an extraction pipe intended to receive said flow of liquid water downstream of the geological reservoir; and a heat exchanger connected to the structure and fitted to the injection pipe and extraction pipe; the installation being equipped with means for implementing the method described above.

[0014] An advantageous aspect of the invention is that the heat exchanger is a liquid/liquid exchanger.

[0015] The invention will be better understood upon reading the following disclosure, given solely by way of non-limiting example, and done with reference to the drawings, wherein:

[0016] FIG. **1** is a schematic representation of an installation for the geological sequestration of carbon dioxide, according to one embodiment of the invention; and

[0017] FIG. **2** is a detailed view of the installation of FIG. **1**.

[0018] FIG. **1** shows an installation **10** for the injection and geological sequestration of carbon dioxide, according to one embodiment of the invention. The installation **10** is suitable for receiving and injecting carbon dioxide **11** into a geological reservoir **12**.

[0019] The geological reservoir **12** is an aquifer reservoir, that is it comprises a reserve **14** of water held under solid ground **16**.

[0020] In the embodiment shown, the geological reservoir **12** is also a submarine reservoir. "Submarine" means that the ground **16** is covered by the sea **18** or, alternatively, by a body of fresh water such as a lake.

[0021] The installation **10** comprises a structure **20**, an injection device **22**, a water extraction device **24** and a heat exchanger **26**. Said heat exchanger **26** can be seen in FIG. **2** showing a detailed view of the structure **20**.

[0022] The system **10** further comprises an electronic control module **27**.

[0023] In the case of a submarine geological reservoir **12**, the structure **20** is preferably floating, as in the embodiment shown. Structure **20** is, for example, a Single Point Anchor Reservoir (SPAR), or a semi-submersible platform, or an Offshore C-Hub™ ship hull.

[0024] In the embodiment shown in FIG. **2**, the structure **20** further comprises a compartment **28** for storing carbon dioxide in a liquid state.

[0025] Preferably, the structure **20** further comprises a device **29** for connecting and discharging liquid carbon dioxide into the compartment **28**. Preferably, the structure **20** further comprises an energy-generating and/or energy-storing member (not shown), as described in the aforementioned FR2107559 application.

[0026] The injection device **22** is able to inject a flow **30** (FIG. **2**) of carbon dioxide into the geological reservoir **12** from the structure **20**. In particular, the injection device **22** is able to: withdraw carbon dioxide in a liquid state from the storage compartment **28**; condition said carbon dioxide to a desired state; and send said conditioned carbon dioxide into the geological reservoir **12**.

[0027] In the embodiment shown, the injection device **22** particularly comprises an injection pipe **32**.

[0028] The injection pipe **32** is intended to receive the flow **30** upstream of the geological reservoir **12**. In the present description, the terms "upstream" and "downstream" refer to the direction of flow through the pipe.

[0029] In the embodiment shown, the injection pipe **32** comprises a long, submerged first pipe **34**, located beneath the structure **20** (FIG. **1**). Preferably, said first pipe **34** is flexible. Upstream of the first pipe **34**, the injection pipe **32** is formed by conduits integral with the structure **20**.

[0030] In the embodiment shown, the injection device **22** further comprises a first well **35**, an injection pump **36**, a lift pump **37** and a conditioning unit **38**.

[0031] The first well **35** (FIG. **1**) is connected to the first pipe **34** and attached to the seabed **16**. The term "well" means a device formed by a wellhead, which protrudes from the ground **16**, and one or more rigid pipes, for example made of steel, which connect said wellhead to the reserve **14**.

[0032] The injection pump **36**, lift pump **37**, and conditioning unit **38** will be described later.

[0033] The water extraction device **24** is able to extract a flow **40** (FIG. **2**) of liquid water from the geological reservoir **12**. In the embodiment shown, the extraction device particularly comprises an extraction pipe **42**.

[0034] The extraction pipe **42** is designed to receive the flow **40** of liquid water downstream of the geological reservoir **12**. In the embodiment shown, the extraction pipe **42** comprises a long, submerged second pipe **44**, located beneath the structure **20**. Preferably, said second pipe **44** is flexible. Upstream of said second pipe **44**, the extraction pipe **42** is formed by conduits integral with the structure **20**.

[0035] In the embodiment shown, the water extraction device **24** further comprises a second well **45**, an extraction pump **46**, a grit removal unit **47** and a treatment unit **48**.

[0036] The second well **45** (FIG. **1**) is connected to the second pipe **44** and attached to the seabed **16**. As mentioned above for the first well **35**, the second well **45** comprises a wellhead, which protrudes from said ground **16**, and at least one pipe which connects said wellhead to the reserve **14**.

[0037] The extraction pump **46** is connected to the second well **45** and is preferably located at the bottom of the well, in the reserve **14**. The grit removal and treatment units **46** and **48** will be described later.

[0038] The heat exchanger **26** is arranged on both the injection pipe **32** and the extraction pipe **42** and is thus able to bring the flow of carbon dioxide **30** and the extracted flow of water **40** into thermal contact.

[0039] In particular, the heat exchanger comprises: a first inlet **50** and a first outlet **52** for the injection pipe **32**; and a second inlet **54** and a second outlet **56** for the extraction pipe **42**.

[0040] Preferably, the heat exchanger, the injection pipe **32** and extraction pipe **42** are configured so that the flows **30** and **40** circulate in counter-current inside said exchanger.

[0041] The heat exchanger **26** is preferably a liquid/liquid exchanger, as in the embodiment shown. In FIG. **2**, the heat exchanger **26** is shown schematically as a serpentine exchanger, but other types of liquid/liquid exchangers can be used. For example, a heat exchanger with an intermediate heat transfer liquid can be used.

[0042] In the embodiment shown, the heat exchanger **26** is arranged on the structure **20**.

[0043] The injection pump **36** of the injection device **22** is arranged on the injection pipe **32**, between the storage compartment **28** and the heat exchanger **26**.

[0044] The lift pump **37** of the injection device **22** is also arranged on the injection pipe **32**, at the bottom of the storage compartment **28**.

[0045] The conditioning unit **38** of the injection device **22** is arranged on the injection pipe **32** downstream of the heat exchanger **26**. The optional conditioning unit **38** comprises means for conditioning the flow of carbon dioxide **30** to a desired state for lowering into the first pipe **34**. For example, the conditioning unit **38** comprises additional heating means in case the temperature of the flow **30** leaving the heat exchanger **26** is still too low.

[0046] The grit removal unit **47** and the treatment unit **48** are located on the extraction pipe **42**, respectively upstream and downstream of the heat exchanger **26**. The treatment unit **48** is configured, for example, to purify the flow of water **40** of heavy metal or salt compounds in high concentration.

[0047] In the embodiment shown, downstream of the treatment unit **48**, the extraction pipe **42** has an outlet **58** leading into the sea **18**. Alternatively, the installation **10** can be configured to use the flow of water **40** in a different way, for example to produce drinking water.

[0048] A method for operating the installation **10** will now be described.

[0049] This method is controlled by the electronic control module **27**, in particular by means of the injection pump **36**, the lift pump **37** and the extraction pump **45**.

[0050] In particular, said method comprises the following steps: generating a flow **30** of carbon dioxide in the injection pipe **32**, for injection into the geological reservoir **12**; in parallel, generating a flow **40** for extracting water from said geological reservoir **12**; and bringing said flows **30** and **40** into thermal contact in the heat exchanger **26**.

[0051] For example, the lift pump **37** and injection pump **36** transfer a flow **30** of liquid carbon dioxide, previously stored in the storage compartment **28**, to heat exchanger **26**. Given the storage conditions, at the first inlet **50** of the heat exchanger **26**, the liquid carbon dioxide is, for example, at a high inlet pressure, of the order of 100 bar, and at an inlet temperature below −20° C., for example between −50° C. and −45° C.

[0052] At the same time, the extraction pump **46** generates, at the second well **45**, a flow **40** of water extracted from the reserve **14** of the geological reservoir **12**. In the structure **20**, said flow **40** first has its grit removed by the grit removal unit **47** before arriving at the second inlet **54** of the heat exchanger **26**. At said second inlet **54**, the flow **40** is liquid, for example at an inlet pressure of around 5 to 6 bar and an inlet temperature of between 60° C. and 70° C.

[0053] The liquid flows **30** and **40** circulate in counter-current through the heat exchanger **26**, and the flow of water **40** transfers heat to the flow **30** of carbon dioxide. At the first outlet **52** of the heat exchanger **26**, the liquid flow of carbon dioxide **30** is, for example, at an outlet pressure close to the inlet pressure, with a deviation of 0 to 5 bar; and at an outlet temperature higher than the inlet temperature.

[0054] The outlet temperature of the flow **30** is preferably in the range 0° C. to 5° C., which is a suitable temperature for injecting liquid carbon dioxide into geological reservoir **12**.

[0055] At the second outlet **56** of the heat exchanger **26**, the liquid flow of water **40** is, for example, at an outlet pressure close to the inlet pressure, with a deviation of 0 to 2 bar, and at an outlet temperature lower than the inlet temperature.

[0056] The outlet temperature of the flow **40** is, for example, in the range of 40° C. to 45° C., a temperature suitable for discharge into the sea.

[0057] The installation **10** thus enables appropriate thermal treatment of both the carbon dioxide to be injected and the water extracted from the same geological reservoir. The installation **10** therefore eliminates the need for additional heating and cooling devices.

[0058] However, downstream of the heat exchanger **26**, the flow of carbon dioxide **30** is optionally reheated by conditioning unit **38**, if the outlet temperature is insufficient.

[0059] Downstream of said conditioning unit **38**, said flow **30**, preferably in a liquid state, reaches the first pipe **34** and is then injected into the geological reservoir **12** at well **35**.

[0060] Extracting the flow of water **40** at the same time as injecting the carbon dioxide facilitates said injection by lowering the pressure in the geological reservoir **12**.

[0061] Downstream of the heat exchanger **26**, the flow of water **40** is treated by treatment unit **48**, which removes pollutant compounds such as mercury from the water. The flow of water **40** is finally discharged into the sea **18** through the outlet **58**.

[0062] Preferably, the injection device **22** performs a continuous injection of carbon dioxide into the geological reservoir **12**, in particular from the storage compartment **28**. "Continuous injection" means that the injection flow rate from injection device **22** to the geological reservoir **12** is always strictly greater than zero. Continuous injection reduces the risk of hydrate formation in the geological reservoir's diffusion channels.

[0063] When the carbon dioxide level in compartment **28** is low, the compartment **28** is fed by means of connection and discharge device **29**. A liquid carbon dioxide transport vessel, for example, is coupled to the device **29** to fill the compartment **28**.

1. A method for operating an installation for the geological sequestration of carbon dioxide, said installation comprising:

a structure, preferentially a floating structure;

an injection device, suitable for injecting a flow of carbon dioxide into a geological reservoir from the structure, said injection device comprising an injection pipe for receiving said flow of carbon dioxide upstream of the geological reservoir; and

an extraction device suitable for extracting a flow of water from said geological reservoir, said extraction device comprising an extraction pipe for receiving said flow of liquid water downstream of the geological reservoir;

wherein:

the installation further comprises a heat exchanger connected to the structure and to the injection and extraction pipes; and

the method comprises the following steps: injecting the flow of carbon dioxide into the geological reservoir from the structure; simultaneously extracting of the flow of water from said geological reservoir; and bringing the flow of carbon dioxide upstream of the geological reservoir into thermal contact, within the heat exchanger, with the flow of water extracted from said geological reservoir.

2. The method according to claim **1**, wherein: the structure comprises a compartment for storing carbon dioxide in a liquid state; and the flow of carbon dioxide into the geological reservoir is injected from said storage compartment.

3. The method according to claim **1**, wherein the injection of the flow of carbon dioxide into the geological reservoir is carried out continuously.

4. The method according to claim **1**, wherein when the flow of carbon dioxide is brought into thermal contact with the extracted flow of water, said flows circulate in counter-current in the heat exchanger.

5. The method according to claim **1**, wherein when the flow of carbon dioxide is brought into thermal contact with the extracted flow of water, each of said flows is in the liquid phase.

6. An installation for the geological sequestration of carbon dioxide, said installation comprising:

a structure, preferentially a floating structure;

an injection device, suitable for injecting a flow of carbon dioxide into a geological reservoir from the structure, said injection device comprising an injection pipe for receiving said flow of carbon dioxide upstream of the geological reservoir;

an extraction device suitable for extracting a flow of water from said geological reservoir, said extraction device comprising an extraction pipe for receiving said flow of liquid water downstream of the geological reservoir; and

a heat exchanger connected to the structure and to the injection and extraction pipes;

the installation being equipped with means for implementing the method according to claim **1**.

7. The installation according to claim **6**, wherein the heat exchanger is a liquid/liquid exchanger.

* * * * *