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(54) Benævnelse: **BATTERILAGER MED KAVERNE**

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CAVERN BATTERY STORAGE DEVICE

The present invention relates to a battery bank for a redox flow battery, a redox flow battery having such a battery bank and a method for producing a battery bank for a redox flow battery. The invention further relates to the use of a cavern, in particular a salt dome cavern, as a battery bank.

A redox flow battery, also known as a flow battery, is an electrochemical energy bank. The classic structure of a redox flow battery consists of a galvanic cell and two separate electrolyte circuits. The galvanic cell is divided into two half-cells by a membrane. Each half-cell is fed by a separate electrolyte circuit, the respective electrolyte being stored in tanks and supplied to the respective half-cell via pumps.

An anolyte flows through a first half-cell, and a catholyte flows through a second half-cell. A charge exchange takes place between the electrolytes. Anolyte and catholyte are reduced and oxidized during charging and discharging, respectively, in order to convert electrical energy into chemical energy and vice versa.

Such a redox flow battery is known, for example, from document DE 10 2012 016 317 A1. The storing capacity of a redox flow battery is limited by the storage volume of the tanks for storing the electrolytes. In known systems, a large number of tank containers for storing electrolyte are mutually interconnected. Additional containers are used to hold a membrane system that serves as a galvanic cell for supplying and releasing energy. Therefore, as the capacity of a redox flow battery increases, the number of containers required to store the electrolytes in such systems increases as well, as does the complexity of the system technology. Further relevant prior art is described in document WO 2009/040521 A1.

The object of the present invention is therefore to specify a battery bank for a redox flow battery, a redox flow battery having such a battery bank and a method for producing a battery bank for a redox flow battery, which do not or at least to a lesser extent have the drawbacks described above and which in particular enable a redox flow battery with a high storage capacity in a simple and inexpensive manner. Further, the use of a cavern is to be specified.

The above-described object is achieved by a battery bank for a redox flow battery according to claim 1, a redox flow battery according to claim 5, a method for producing a battery bank for a redox flow battery according to claim 12 and the use of a cavern according to claim 13. Advantageous embodiments of the invention will become apparent from the dependent claims and the description below.

Due to the electrolyte being accommodated in a cavern, large amounts of electrolyte can also be stored in a single bank, i.e. a single cavity. For example, caverns previously used as gas caverns can be utilised for this purpose. There is therefore no need for above-ground containers or tanks to store electrolyte. As a result, the system and cost expense for storing electrolyte for redox flow batteries with high capacity can be reduced, since no widely branched pipe system is required to interconnect a plurality of tanks or containers.

If a cavern is referred to in the present case, it is an underground cavity that can be arranged, for example, several hundred meters beneath the surface of the earth.

The electrolyte stored in the battery bank is, for example, a catholyte or an anolyte for a redox flow battery.

For example, the electrolyte can have a storage capacity, i.e. energy density, of 25 watt-hours per liter (W*h/L).

According to an advancement of the battery bank, it is provided that the cavern be a salt dome cavern. Such a salt dome cavern can be created in a known manner by rinsing out or mining out a salt layer underground. Known methods can thus be used to create an underground cavity which serves as a battery bank for storing electrolyte for a redox flow battery. Alternatively, an existing cavern that was originally intended for storing gas can be used to store electrolyte for a redox flow battery.

According to alternative configurations, it can be provided that the cavern be delimited, at least in sections, in particular completely, by rocks, in particular granite.

It is provided according to the invention that the electrolyte has brine and polymer, in particular liquid polymer. Such an electrolyte has the advantage of being more eco-friendly than acid-based electrolytes.

The use of brine and polymer as the electrolyte can ensure that, for example, existing salt dome caverns originally intended for storing gas can be converted into battery banks for a redox flow battery without additionally burdening the environment. For example, a gas cavern already flooded with brine can be connected to a circuit of a redox flow battery, wherein the brine can be mixed with polymer during circulation. The brine can be enriched with polymer by adding polymer to the brine above ground. In this manner, large storage capacities can be tapped as battery banks for a redox flow battery with comparatively little effort.

When brine is referred to presently, it is an aqueous, saturated salt solution.

According to an advancement of the battery bank, it is provided that the cavity has a volume (void volume) in an inclusive range from 70,000 m^3 (seventy thousand cubic meters) to 500,000 m^3 (five hundred thousand cubic meters) or 500,000 m^3 (five hundred thousand cubic meters) to 800,000 m^3 (eight hundred thousand cubic meters), in particular has 600,000 m^3.

These volumes are orders of magnitude in which, for example, salt dome caverns for gas storage are usually produced. In this manner, large amounts of electrolyte can be stored in a single battery bank at low system expense. For example, a cavern having a volume of approximately 600,000 m^3 (six hundred thousand cubic meters) can serve as a battery bank for storing electrolyte.

New salt dome caverns can be created as battery banks for a redox flow battery, or existing salt dome caverns for storing gas can be converted into battery banks for a redox flow battery. It is understood that, in addition to salt caverns, other types of caverns, such as, for example, granite caverns or the like, may also be suitable for storing electrolyte for a redox flow battery.

Depending on the nature of the layers of earth, it can be provided that the volume of a cavern, which is to serve as a battery bank for a redox flow battery, is 100,000 m^3 (one hundred thousand cubic meters) to 1,000,000 m^3 (one million cubic meters). If the geological and technical framework conditions allow it, the volume or void volume of a cavern which is to serve as a battery bank for a redox flow battery is freely scalable and can also hold more than a million cubic meters of electrolyte.

According to a further aspect, the invention relates to a redox flow battery, having one or more redox flow cells and at least two battery banks for supplying electrolyte to the one or more redox flow cells. At least one of the battery banks is designed in a manner according to the invention.

While the electrolyte of at least one circuit of such a redox flow battery is stored underground in a cavern, for example a catholyte, the electrolyte of a second circuit of the redox flow battery, for example an anolyte, can be stored in a conventional manner above ground in containers or tanks. All in all, the storage of at least one electrolyte of a redox flow battery underground already reduces the above-ground footprint and system technology for tanks or containers interconnected above ground.

If a redox flow cell is referred to presently, it is a galvanic cell divided into at least two half-cells by one or more membranes. An anolyte flows through a first half-cell, and a catholyte flows through a second half-cell. A charge exchange takes place between the electrolytes. Anolyte and catholyte are reduced and oxidized during charging and discharging, respectively, in order to convert electrical energy into chemical energy and vice versa.

According to an advancement of the redox flow battery, it is provided that two or more battery banks be provided for supplying electrolyte to the one or more redox flow cells, wherein at least two battery banks are designed in a manner according to the invention. According to this embodiment, at least two battery banks for storing electrolyte are arranged underground in caverns. In this manner, large stock volumes and storage capacities of a redox flow battery can be mapped, while the system expense is minimised. For example, a first battery bank according to the invention can store an anolyte and a second battery bank separate from the first battery bank can store a catholyte.

According to an alternative embodiment of a redox flow battery, it is provided that the redox flow battery have exactly two battery banks for supplying electrolyte to the one or more redox flow cells, wherein the battery banks are designed in a manner according to the invention. According to this embodiment, a redox flow battery having a high storage volume or a high storage capacity can be implemented in a simple manner, wherein the system technology can be minimised based on only two battery or electrolyte banks. For example, a plurality of redox flow cells can be fed from exactly two separate, underground caverns and supplied with electrolyte, wherein the first battery bank stores an anolyte and the second battery bank separate from the first battery bank stores a catholyte.

While the battery bank can be implemented at least partially, preferably exclusively underground, in caverns, the arrangement of the one or more redox flow cells, which are also referred to as membrane stacks, can preferably be above ground.

According to an advancement of the redox flow battery, it is provided that a first pipe string and a second pipe string for supplying and removing electrolyte lead to the cavern, wherein the pipe strings are in particular nested in one another. For example, existing pipe strings that still consist of a previous utilisation of the cavern for gas storage can continue to be used or modified for electrolyte supply and/or withdrawal.

The pipe strings can be nested in one another in terms of a space-saving arrangement. For example, the first pipe string can be suspended in a second pipe string.

With regard to the system technology of a redox flow battery, which can have a widely branched line system made of metal, it is advantageous to use brine with polymer as the electrolyte, since the metal pipes are not affected by the brine.

If it is said in the present case that the first and the second pipe strings lead into the cavern, this means that at least one pipe end of the respective pipe string extends into the cavity volume of the cavern provided for storing electrolyte.

According to an advancement of the redox flow battery, it is provided that one end of the first pipe string be associated with a cavern bottom and one end of the second pipe string be associated to a cavern roof.
During battery operation, stratification of the electrolyte can occur during the charging or discharging process of the battery. For example, during a discharging process, charged electrolyte can be arranged, i.e. concentrated, above discharged electrolyte in the area of the cavern roof, while discharged electrolyte is accumulated in the area of the cavern bottom. During the discharging process, charged electrolyte in the roof area of the cavern can therefore be withdrawn via the second pipe string and discharged electrolyte in the area of the cavern bottom can be returned to the cavern via the second pipe string.
The power release and input capacities of a redox flow cell depend on the one hand on the energy density and the volume of the electrolyte and further on the available membrane area within the redox flow cells, via which a charge exchange can take place.
In order to achieve a flexible adaptation of the power consumption and release of the redox flow battery, a multitude of redox flow cells can be provided, wherein the redox flow cells are able to be arranged in a cascade connection.
Due to the cascade connection, the redox flow cells can be switched on in parallel or in series with one another or hidden from the energy flow in order to meet the respective operating conditions with regard to energy storage or power release.
The redox flow battery can have a capacity in an inclusive range of 12.5 to 25 gigawatt-hours (GWh). This means that the proposed redox flow battery can be used to achieve storage capacities that have been expanded to include capacities of nuclear power plants.
The redox flow battery can serve as a buffer storage for wind or solar energy plants. In this respect, it is advantageous for a redox flow battery not to have any memory effect or any damage due to deep discharge occur.
According to a further aspect, the invention relates to a method for producing a battery bank for a redox flow battery, wherein at least the following method steps being carried out:

- provision of a cavity for storing electrolyte, wherein the cavity is a cavern;
- provision of electrolyte in the cavern.

In the process step "provision of a cavity for storing electrolyte, wherein the cavity is a cavern", for example, existing caverns that were originally provided for gas storage can be employed. Alternatively, a new cavern for storing electrolyte can be created using known methods, wherein, for example, the mining of a salt dome may occur. In this process, the brine can remain in the cavern and treated with polymer.

Electrolyte can be fed into the cavern after or during the mining of the cavern. Thus, for example, a salt dome cavern already flooded with brine can be successively mixed with polymer, in particular liquid polymer, in a circulating brine circuit in order to provide the electrolyte required for a redox flow battery.

Alternatively, a gas cavern can be filled or flooded directly with an electrolyte made of brine and polymer and thus used as a battery bank for a redox flow battery.

According to a final aspect, the invention relates to the use of a cavern, in particular a salt dome cavern, as a battery bank for accommodating electrolyte for a redox flow battery. In particular, it can be a salt dome cavern that was originally provided or used for gas storage.

The invention is explained in more detail below on the basis of drawings depicting an exemplary embodiment. Brief description of the schematic drawings:

Fig. 1 shows a redox flow battery according to the invention having a battery bank according to the invention.

Fig. 2 shows a battery bank according to the invention for a redox flow battery.

Fig. 1 shows a redox flow battery 2. The redox flow battery 2 has a first battery bank 4 and a second battery bank 6. The first battery bank 4 has a cavity 8, in which the electrolyte 10 is stored. The cavity 8 is a cavern 8.

The second battery bank 6 has a cavity 12, in which the electrolyte 14 is stored. The cavity 12 is a cavern 12.

The electrolyte 10 has brine and liquid polymer. The electrolyte 14 also has brine and liquid polymer. Presently, the electrolyte 10 forms the anolyte. The electrolyte 14 forms the catholyte.

The cavern 8 has a cavity volume for accommodating electrolyte 10 of 600,000 m^3. The cavern 12 has a cavity volume for accommodating electrolyte 14 of 600,000 m^3.

The redox flow battery 2 has a redox flow cell 16. The redox flow cell 16 is divided by a membrane 18 into a first half-cell 20 and a second half-cell 22. A first electrode 24 is associated with the first half-cell 20. A second electrode 26 is associated with the second half-cell 22. Electrical energy can be withdrawn from and supplied to the redox flow cell 16 via the electrodes 24, 26.

The first half-cell 20 is connected to the first battery bank device 4 via pipelines 28. The second half-cell 22 is connected to the second battery bank 6 via pipelines 30. The electrolyte 10 is conveyed through the first half-cell 20 with the aid of a pump 31. The electrolyte 12 is conveyed through the second half-cell 22 with the aid of a pump 32. In this manner, two separate electrolyte circuits are formed.

The redox flow battery 2 can have a multitude of redox flow cells 16, which are connected to one another in a cascade connection. The present redox flow battery 2 has a capacity of 15 gigawatt-hours (GWh).

Fig. 2 shows a battery bank 34, which can serve as a battery bank 4 or 6 of the redox flow battery 2 shown in Figure 1. Electrolyte 36 is accommodated in the battery bank 34. The electrolyte 36 can be withdrawn from or supplied to the battery bank 34 via a conveyor system 38.

Presently, the battery bank 34 has a salt dome cavern 35, which has been introduced into a salt dome 40 by mining and forms a cavity 35 for accommodating electrolyte 36.

The conveyor system 38 has a standpipe 42, an anchor pipe string 44, a feed pipe string 46, a protective line 48, an electrolyte withdrawal line 50 and an electrolyte return line 52. The electrolyte return line 52 is a first pipe string 52, which leads into the salt dome cavern 35. A first end 51 of the first pipe string 52 is associated with a cavern bottom 54.

The electrolyte withdrawal line 50 is a second pipe string 50 which leads into the salt dome cavern 35. A first end 53 of the second pipe string 50 is associated with a cavern roof 56.

During the discharge process of a redox flow battery, which can be configured, for example, as a redox flow battery 2 according to Fig. 1, charged electrolyte 36 is withdrawn via the second pipe string 50 in the area of the cavern roof 56 and supplied to one or more redox flow cells.

After the chemical energy of the electrolyte 36 has been converted into electrical energy in one or more redox flow cells, discharged electrolyte 36 can be returned to the cavern bottom 54 of the salt dome cavern 35 via the first pipe string 52. This results in stratification within the salt dome cavern 35, wherein charged electrolyte 36 is associated with, i.e. concentrated in, the cavern roof 56 and discharged electrolyte 36 is associated with, i.e. concentrated in, the cavern bottom 54.

The pumps 31, 32 can be operated in two directions, so that the electrolyte circuits can also be operated in two directions. In this case, the second pipe string 50 is an electrolyte return line and the first pipe string 52 is the electrolyte withdrawal line. The pumps 31, 32 can be arranged inside or outside the cavities 8, 10.

Presently, therefore, a salt dome cavern 35 is used as a battery bank 34, in which an electrolyte 36 provided for being supplied to a redox flow battery is stored in the salt dome cavern 35.

The battery bank 34 can be produced on the one hand by converting an existing gas cavern, which has been generated in a salt dome by mining, into a battery bank for storing electrolyte. For example, the battery bank 34 can be an already flooded gas dome cavern filled with brine. Polymer can then be successively supplied to the brine in a cyclic process to provide an electrolyte for a redox flow battery in the cavern.
Alternatively, a cavern can be built into a salt dome specifically for use as a battery bank for a redox flow battery.

Reference numerals

2	redox flow battery
4	first battery bank
6	second battery bank
8	cavity/cavern
10	electrolyte/anolyte
12	cavity/cavern
14	electrolyte/catholyte
16	redox flow cell
18	membrane
20	first half-cell
22	second half-cell
24	first electrode
26	second electrode
28	pipelines
30	pipelines
31	pump
32	pump
34	battery bank
35	salt dome cavern/cavity
36	electrolyte
38	conveyor system
40	salt dome
42	standpipe
44	anchor pipe string
46	feed pipe string
48	protective line

50 electrolyte withdrawal line/second pipe string
51 first end of first pipe string
52 electrolyte return line/first pipe string
53 first end of second pipe string
54 cavern bottom
56 cavern roof

BATTERILAGER MED KAVERNE

Patentkrav

1. Batterilager til et redox-flow-batteri, med en kavitet (8, 12, 35), i hvilken der er lagret elektrolyt (10, 14, 36), hvor elektrolytten (10, 14, 36) er tilvejebragt til tilførsel til en eller flere redox-flow-celler (16), hvor kaviteten (8, 12, 35) er en kaverne (8, 12, 35), og hvor elektrolytten (10, 14, 36) indeholder brine og polymer.

2. Batterilager ifølge krav 1, kendetegnet ved, at kavernen (35) er en salthorstkaverne (35).

3. Batterilager ifølge et af kravene 1 eller 2, kendetegnet ved, at elektrolytten (10, 14, 36) indeholder brine og flydende polymer.

4. Batterilager ifølge et af de foregående krav, kendetegnet ved, at kaviteten (8, 12, 35) har et volumen i et område fra 70.000 m^3 til 500.000 m^3 eller 500.000 m^3 til 800.000 m^3, særligt på 600.000 m^3.

5. Redox-flow-batteri, med

- en eller flere redox-flow-celler (16) og
- i det mindste to batterilagre (4, 6, 34) til forsyning af den ene eller de flere redox-flow-celler (16) med elektrolyt (10, 14, 36), hvor i det mindste et af batterilagrene (4, 6, 34) indeholder en kavitet (8, 12, 35), i hvilken der er lagret elektrolyt (10, 14, 36), hvor elektrolytten (10, 14, 36) er tilvejebragt til tilførsel til den ene eller de flere redox-flow-celler (16), kendetegnet ved, at
- kaviteten (8, 12, 35) er en kaverne (8, 12, 35), f.eks. en salthorstkaverne (35), en granitkaverne eller lignende.

6. Redox-flow-batteri ifølge krav 5, kendetegnet ved, at

- der er tilvejebragt to eller flere batterilagre (4, 6, 34) til forsyning af den ene eller de flere redox-flow-celler (16) med elektrolyt (10, 14, 36), hvor i det mindste to batterilagre (4, 6, 34) hver især indeholder en kavitet (8, 12, 35), i hvilken der er lagret elektrolyt (10, 14, 36), hvor elektrolytten (10, 14, 36) er tilvejebragt til tilførsel til den ene eller de flere redox-flow-celler (16), og hvor den pågældende kavitet (8, 12, 35) er en kaverne (8, 12, 35), f.eks. en salthorstkaverne (35), en granitkaverne eller lignende, og/eller

- at der er tilvejebragt nøjagtigt to batterilagre (4, 6, 34) til forsyning af den ene eller de flere redox-flow-celler (16) med elektrolyt (10, 14, 36), hvor batterilagrene (4, 6, 34) hver især indeholder en kavitet (8, 12, 35), i hvilken der er lagret elektrolyt (10, 14, 36), hvor elektrolytten (10, 14, 36) er tilvejebragt til tilførsel til den ene eller de flere redox-flow-celler (16), og hvor den pågældende kavitet (8, 12, 35) er en kaverne (8, 12, 35), f.eks. en salthorstkaverne (35), en granitkaverne eller lignende.

7. Redox-flow-batteri ifølge et af kravene 5 eller 6, kendetegnet ved, at en første rørstreng (52) og en anden rørstreng (50) til elektrolyttilførsel og til elektrolytudtagning munder ud i kavernen (8, 12, 35), hvor rørstrengene (50, 52) særligt er indlejrede i hinanden, hvor særligt en ende (51) af den første rørstreng er tilordnet en kavernebund (54), og en ende (53) af den anden rørstreng (50) er tilordnet et kavernetag (56).

8. Redox-flow-batteri ifølge et af de foregående krav 5 til 7, kendetegnet ved, at

- der er tilvejebragt et flertal af redox-flow-celler (16), hvor redox-flow-cellerne (16) er anbragt i en kaskadekobling,

og/eller

- redox-flow-batteriet (2) har en kapacitet i et område fra 12,5 til 25 gigawatt-timer, særligt på 15 gigawatt-timer.

9. Redox-flow-batteri ifølge et af kravene 5 til 8, kendetegnet ved, at kavernen (35) er en salthorstkaverne (35).

10. Redox-flow-batteri ifølge et af kravene 5 til 9, kendetegnet ved, at elektrolytten (10, 14, 36) indeholder brine og polymer, særligt flydende polymer.

11. Redox-flow-batteri ifølge et af de foregående krav 5 til 10, kendetegnet ved, at kaviteten (8, 12, 35) har et volumen i et område fra 70.000 m^3 til 500.000 m^3 eller 500.000 m^3 til 800.000 m^3, særligt på 600.000 m^3.

12. Fremgangsmåde til fremstilling af et batterilager til et redox-flow-batteri, hvor i det mindste de følgende fremgangsmådetrin gennemgås:

- tilvejebringelse af en kavitet (8, 12, 35) til opbevaring af elektrolyt (10, 14, 36), hvor kaviteten (8, 12, 35) er en kaverne (8, 12, 35);

- tilvejebringelse af elektrolyt (10, 14, 36) i kavernen (8, 12, 35), kendetegnet ved,
- at elektrolytten (10, 14, 36) indeholder brine og polymer.

13. Anvendelse af en kaverne, særligt en salthorstkaverne, som batterilager (4, 6, 34) til opbevaring af elektrolyt (10, 14, 36) til et redox-flow-batteri (2), kendetegnet ved, at elektrolytten (10, 14, 36) indeholder brine og polymer.

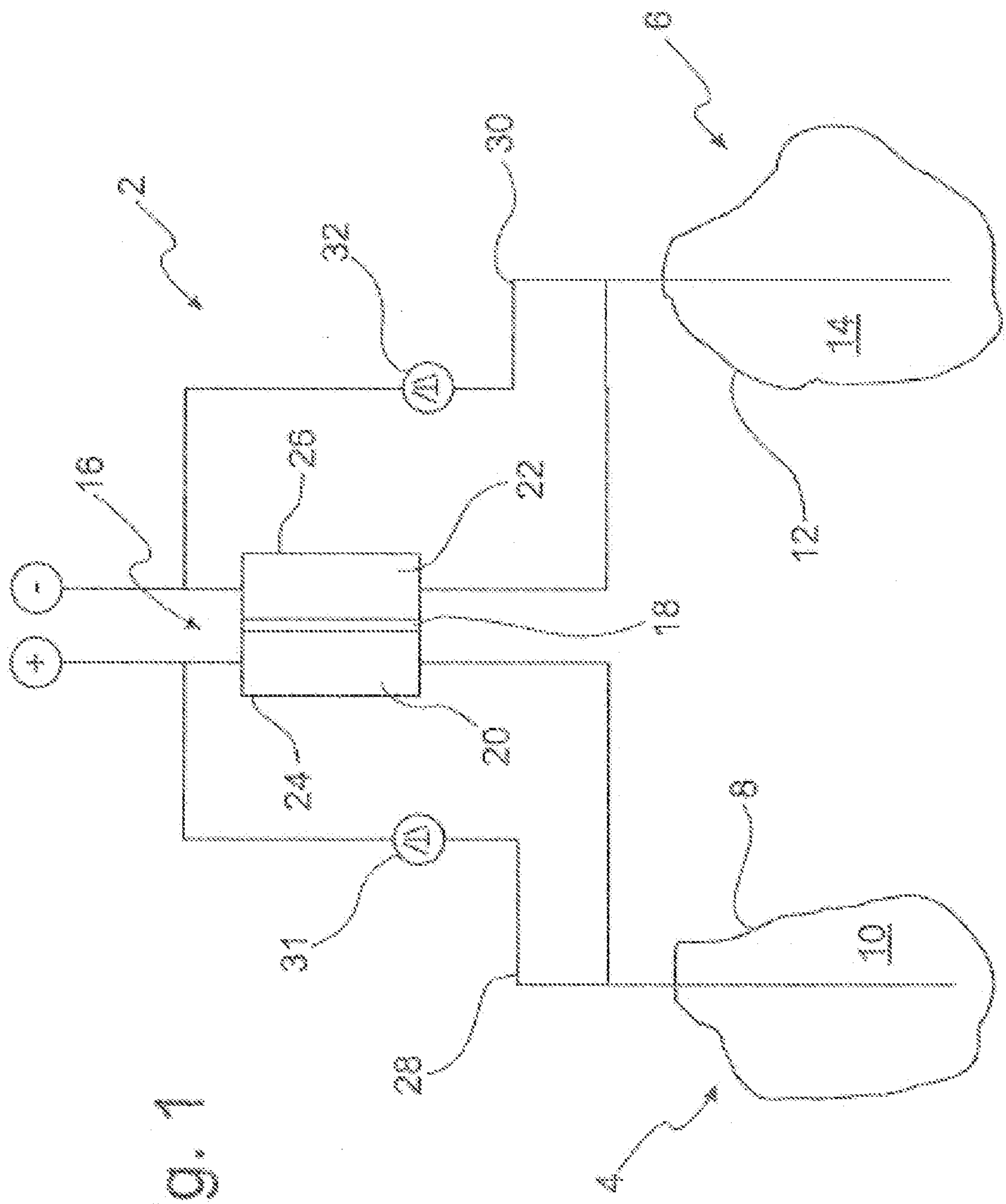

Fig. 1

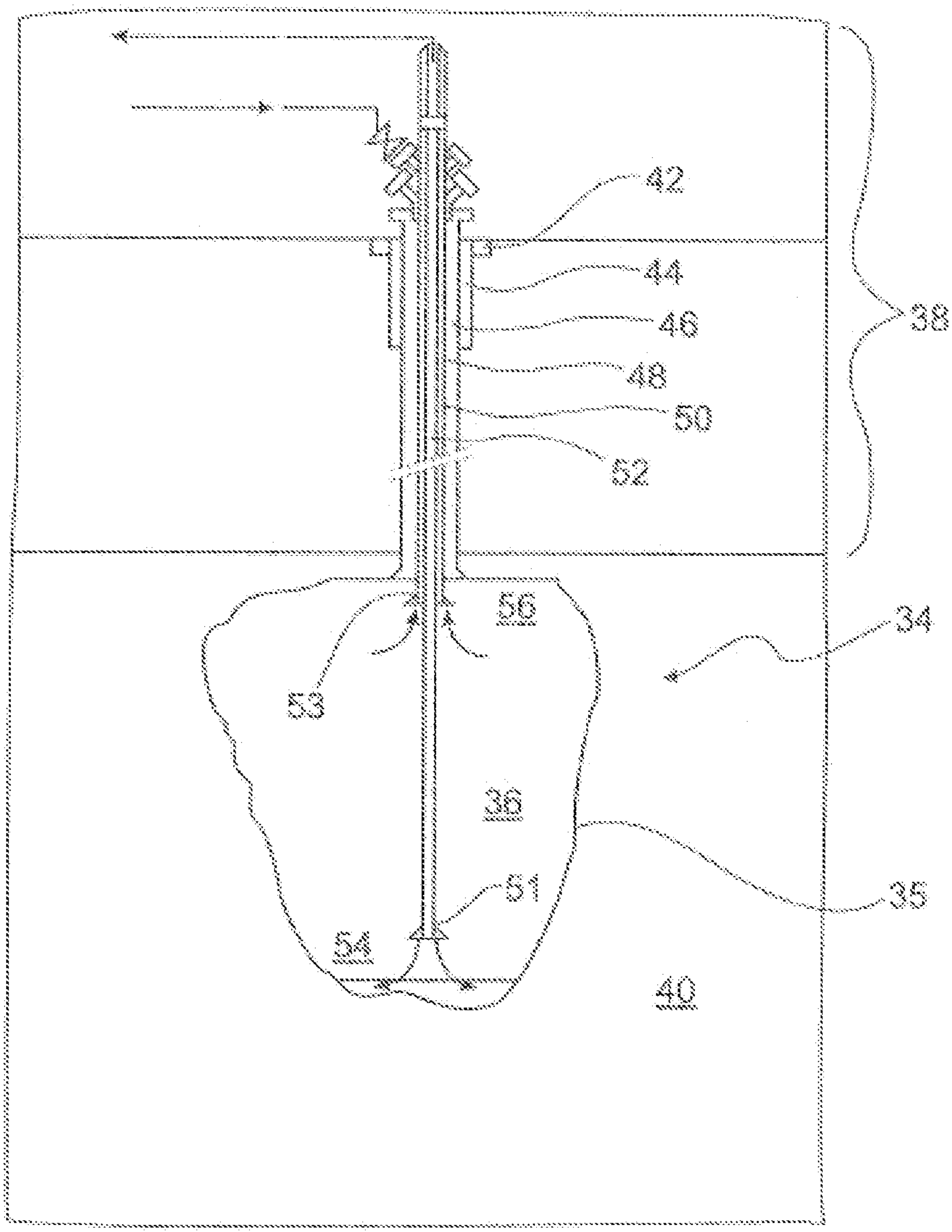

Fig. 2