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(54) Power and/or distribution transformer equipped with on-load tap-changer

(57) A power and/or distribution transformer comprising:

- a tank provided with a magnetic core, high- and low-voltage windings, adjustment windings. insulating partitions made of solid material which are interposed between the high- and low-voltage windings and a dielectric and cooling fluid;
- an on-load tap changer which comprises:
- at least one selector which is immersed in a lubricating fluid;
- at least one diverter switch which comprises arc contacts and a dielectric arc-quenching fluid;

characterized in that the dielectric and cooling fluid of the transformer and/or the dielectric and arc-quenching fluid and/or the lubricating fluid of the selector are liquid perfluoropolyethers, and in that the tank and the diverter switch are each provided with a filter for reducing chemically reactive gas species generated by the decomposition of the fluids.

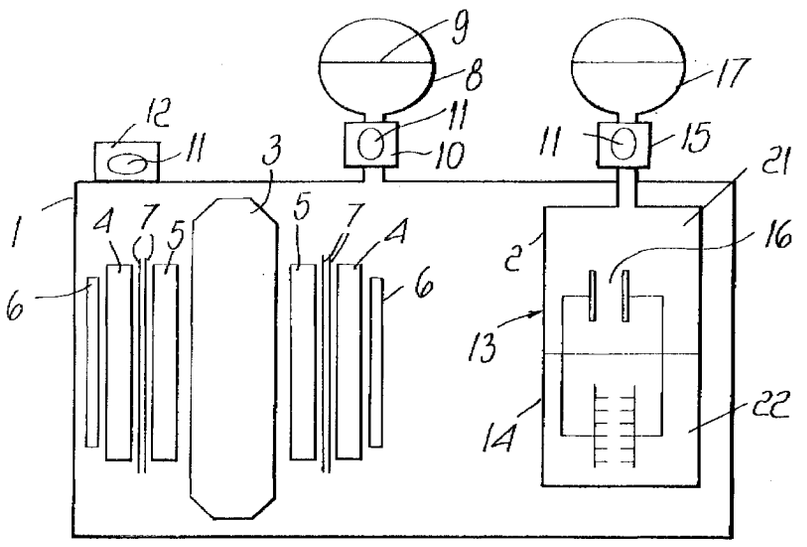

Fig.1

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Description

[0001] The present invention relates to a power and/or distribution transformer equipped with an on-load tap changer.

[0002] It is known that the tap changer connected to the transformer is meant to vary the transformation ratio of the transformer so that the voltage can be adjusted according to the requirements of the service. Power and/or distribution transformers provided with an on-load tap-changer normally use fluids which have different functions:

- the fluid contained in the transformer acts as dielectric and coolant;
- the fluid contained in the selector of the tap changer also acts as lubricant and can be the same fluid as in the transformer (if the tap changer is inserted in the same tank as the transformer) or a different fluid;

finally, the fluid contained in the diverter switch of the tap changer has a dielectric and arc-quenching function and is always physically separate from the fluid of the transformer. Said fluid is normally subjected to maintenance and is replaced after a fixed number of cycles, usually after every 50,000 actuations performed by the tap changer.

[0003] Usually, the fluid used is a liquid, for example mineral oil. Some manufacturers use gases, such as nitrogen, sulfur hexafluoride, hexafluoroethane, and the like, either alone or in mixed solutions, such as for example sulfur hexafluoride together with perfluorocarbon.

[0004] However, this solution, which entails the use of mineral oil, has a drawback. because mineral oil is flammable and generates explosive gases by decomposing; accordingly, a transformer with an on-load tap changer in mineral oil is flammable and can entail the risk of explosion.

[0005] Transformers using liquids such as perfluorocarbon are not flammable and are not subject to the risk of explosion, but still have the drawback of being bulky and of having a certain constructive complexity.

[0006] Gases such as sulfur hexafluoride, in order to act correctly as dielectrics, either alone or in mixed solutions, must be kept at high pressure, with consequent constructive complications and the risk of explosion.

[0007] Further, owing to their low cooling performance, their use entails large volumes and therefore transformers that contain these gases are bulky and, as mentioned, subject to the risk of explosion.

[0008] The aim of the present invention is to provide a power and/or distribution transformer provided with on-load tap changer which is not flammable.

[0009] Within the scope of this aim, an object of the present invention is to provide a power and/or distribution transformer provided with on-load tap changer which is not potentially explosive.

[0010] A further object of the present invention is to provide a power and/or distribution transformer provided with on-load tap changer which has a compact volume and is constructively simple.

[0011] A further object of the present invention is to provide a power and/or distribution transformer provided with on-load tap changer in which the liquids used inside the transformer and the tap changer are not toxic.

[0012] A further object of the present invention is to provide a power and/or distribution transformer provided with on-load tap changer in which. if the decomposition of the liquids contained in the transformer and in the tap-changer leads to toxic decomposition products, said products can be adsorbed and destroyed.

[0013] A further object of the present invention is to provide a power and/or distribution transformer provided with on-load tap changer in which the liquids are substantially maintenance-free.

[0014] A further but not the least object of the present invention is to provide a power and/or distribution transformer provided with on-load tap changer which is highly reliable, relatively easy to manufacture and at low costs.

[0015] This aim, these objects and others which will become apparent hereinafter are achieved by a power and/or distribution transformer which comprises:
a tank provided with a magnetic core, high- and low-voltage windings, adjustment windings, insulating partitions made of solid material which are interposed between said high- and low-voltage windings and a dielectric and cooling fluid;

- an on-load tap-changer which comprises:
- at least one selector which is immersed in a lubricating fluid;
- at least one diverter switch which comprises arc contacts and a dielectric arc quenching fluid;

characterized in that the dielectric and cooling fluid of said transformer and/or the dielectric and arc-quenching fluid and/or the lubricating fluid of said selector are liquid perfluoropolyethers, and in that said tank and said diverter switch are each provided with a filter for reducing chemically reactive gas species generated by the decomposition of said fluids.

[0016] Further characteristics and advantages of the invention will become apparent from the description of preferred embodiments of the power transformer according to the invention. illustrated only by way of non-limitative example in the accompanying drawings, wherein:

- Figure 1 is a schematic view of a power and/or distribution transformer provided with on-load tap changer, according to a first embodiment of the present invention;
- Figure 2 is a schematic view of a power and/or distribution transformer provided with on-load tap

changer, according to a second embodiment of the present invention; and

- Figure 3 is a schematic view of a power and/or distribution transformer provided with on-load tap changer according to a third embodiment of the present invention.

[0017] With reference to the above figures, and in particular initially to Figure 1, the power and/or distribution transformer according to the invention comprises a tank 1 which accommodates the actual transformer together with the on-load tap changer 13.

[0018] The power transformer comprises a magnetic core 3, a high-voltage winding 4, a low-voltage winding 5 and adjustment windings 6.

[0019] Said high-voltage and low-voltage windings 4 and 5 are interposed between insulating partitions 7 made of solid material which are meant to subdivide the insulation distance.

[0020] The tank l is filled with a fluid which has a dielectric and transformer cooling function and is designated by the reference numeral 20.

[0021] The tank l has, at its top, surge tank means 8 provided with an elastic sealing membrane 9 to allow the thermal expansion of the liquid 20 contained in the tank 1.

[0022] In the portion that provides the connection between the tank l and the surge tank 8 there is a gas protection device 10 which is sensitive to the pressure of the gases generated due to abnormal operation such as Buchholz relays, which are connected to means 18 for collecting said gases, inside which an active filter 11 is inserted: said filter is the subject of Italian Patent Application no. MI97A 002804.

[0023] The filter 11 is meant to neutralize toxic gaseous chemical species which develop clue to the decomposition of the liquid that is present in the tank 1.

[0024] The filter 11 can be located either/both in liquid phase or/and in gaseous phase. Preferably, the filter 11 can use as scavanger base compounds such as substances of the Jeffamine family or soda-lime or the like.

[0025] On the top of the tank 1 there is also an explosion-proof protective device 12 inside which there is, in a similar manner, an additional filter 11.

[0026] The tank 1 contains the on-load tap changer 13, which is meant to vary the transformation ratio of the transformer, so that the voltage can be adjusted according to the requirements of the service.

[0027] The on-load tap changer 13 has its own external tank and is constituted by a selector 14 which is electrically series-connected to at least one diverter switch 2. The diverter switch 2 has arc contacts 16 and is filled with a dielectric and arc-quenching fluid 21, which is separated from the liquid that is present in the selector, designated by the reference numeral 22.

[0028] The liquid 22 of the selector is a dielectric fluid which mainly acts as lubricant for the kinematic systems of the selector.

[0029] The tap changer 13, and particularly the diverter switch 2, is connected to expansion means 17 to allow the expansion of the liquid 21 that is present in the diverter switch 2, which can be provided with an additional active filter 11.

[0030] In the portion connecting the diverter switch 2 and the expansion means 17 there are protection means 15 which are sensitive to the pressure of the gases generated by the electric arcs in the diverter switch 2, such as a Buchholz relay, connected to means 19 for collecting said gases, inside which there is another active filter 11.

[0031] The on-load tap changer 13 can be of the sealed type, in order to saturate the liquid with oxygen and accordingly eliminate the formation of decomposition products of the fluid which are stable and harmful to the environment.

[0032] Figure 1 is a view of the embodiment of the invention in which the tap changer 13 is contained in the tank 1; Figure 2 is instead a view of a second embodiment, in which the tap changer 13 is partially internal to the tank 1 of the transformer or external to the transformer, as shown in Figure 3 (third embodiment).

[0033] In particular, the selector 14 of the tap changer 13 can be directly immersed in the same fluid 20 of the transformer and the fluids 20 and 22 therefore coincide.

[0034] The fluid 21 is instead always separate from the fluid 20, although it may be chemically identical.

[0035] The invention is further characterized in that the fluids 20, 21 and 22 are liquid perfluoropolyethers having the following chemical formula:

EndgroupA-O-(C3F6O)n-(CF2O)m-EndgroupB

EndgroupA-O-(C2F4O)n-(CF2O)m-EndgroupB

where EndgroupA and EndgroupB are mutually identical or different and are chosen between CF3 and CF_2H.

[0036] Perfluoropolyethers are nonflammable, do not generate explosive gases, and are not toxic. These fluids can be chosen over a wide range of relative molecular masses and therefore of viscosities; from a fraction of one cSt to tens and hundreds of cSt, and can be hydrogenated or not at their endgroups.

[0037] In view of the functions of the various fluids 20, 21 and 22, values deemed to be optimum have been tested experimentally.

[0038] The fluid 20, which has a mainly dielectric and cooling function. preferably has a viscosity of less than 10 cSt at constant temperature.

[0039] The fluid 21, which instead has a mainly arequenching function, preferably has at least one hydrogenated endgroup.

[0040] Finally. the fluid 22, which is mainly meant to lubricate the kinematic systems of the selector 14, preferably has a viscosity of more than 1 cSt at room tem-

perature.

[0041] In particular, the dielectric properties of perfluoropolyethers (and particularly of the fluid 20) allow to simplify the construction and design of the transformer. Dielectric liquids normally reduce their dielectric strength very significantly over long distances (more than 10 mm). Accordingly, the insulating partitions 7 are usually interposed in the dielectric space between the high- and low-voltage windings 4 and 5 of the transformer, subdividing the distances in the liquid.

[0042] The number of these subdivisions and the overall distance depend on the dielectric characteristics of the liquid and on the humidity content thereof.

[0043] The excellent dielectric properties over long distances (more than 10 mm) of perfluoropolyethers containing less than 10 ppm of humidity allow to eliminate some partitions 7 and reduce overall distances.

[0044] In particular, given the following parameters:

N = number of insulating partitions 7 made of solid material interposed between the high- and low-voltage windings 4 and 5

D* = overall distance, through liquid only between the high-voltage winding 4 and the low-voltage winding 5, given by the average distance D between the high-voltage winding 4 and the low-voltage winding 5 minus the sum of the thicknesses of said insulating partitions 7. it has been observed that the transformer can be designed so that the number of insulating partitions and the overall distance depend on the test voltage at industrial frequency of the transformers V*, according to the following relationship:

$$N \times D^* <= 5 \times (V^*)^2$$

where D* is expressed in meters and V* is expressed in kilovolts, and the above relation holds for V* >= 140 kV.

[0045] This entails a reduction in the volumes of the transformer and a constructive simplification. Perfluoropolyethers are non-toxic liquids which have no environmental impact; however, their decomposition products can include products which are toxic or have an impact on the environment, particularly on the greenhouse effect.

[0046] Therefore, in order to eliminate the toxic products, active filters 11 are used to adsorb and eliminate said toxic products.

[0047] The fluid 20 can decompose due to partial discharges or by heat, or can decompose due to an electric arc (in case of malfunction of the transformer, for example a short circuit), and therefore the filter is located preferably both in the gas collection device 19 and in the explosion-proof device 12.

[0048] The fluid 21 instead decomposes during normal diverters of the tap-changer 13 and therefore the filter 11 is located at the gas collection device 19 and/or at the expansion means 17.

[0049] As regards the elimination of products having an environmental impact, it has been observed that in the presence of abundant oxygen the stoichiometry of the decomposition is such that no environmentally-damaging products form.

[0050] For this purpose, the diverter switch 2 is provided with an expansion tank 17, as described above, which is filled with oxygen; therefore the liquid 21 is saturated with oxygen, which dissolves up to approximately 30% by volume at room temperature.

[0051] The presence of oxygen which saturates the liquid 21 of the diverter switch allow to shift the reaction for producing the gases generated by the decomposition of the liquid during the electric arc. It has in fact been observed experimentally that the presence of oxygen shifts the main reaction from the formation of CF4 to the formation of COF_2 as preferential product.

[0052] In oxygen, more than 96% reactive gases is produced, and only a few percent stable gases are produced. The amount of oxygen required for the entire typical operating life of the transformer can be contained in an expansion tank 17 which has minimal dimensions and acceptable costs.

[0053] The liquid perfluoropolyethers having the above described formula have, as mentioned, endgroups which can be CF_2H (one or both) or CF_3 (no more than one). The presence of the CF_2H endgroup is extremely important for environmental impact, since it causes the molecule to be reactive in the upper atmosphere and therefore does not contribute to the greenhouse effect.

[0054] Another advantage arising from the use of liquid perfluoropolyether is the fact that these liquids are not subject to loss of their dielectric and arc-quenching properties due to their use as quenching media, i.e., they are not subject to aging as instead occurs for the mineral oil normally used as fluid in transformers.

[0055] This means that in an on-load tap changer in which the fluid 21 is normally replaced every 50,000 actuations (if mineral oil is used), the fluid 21 becomes essentially maintenance-free when using liquid perfluoropolyether.

[0056] It should be noted that the fluid 21 that is present in the diverter 2 or breaker chamber is always separated from the fluid 22 that is present in the selector, regardless of the position that the tap changer 13 assumes with respect to the tank 1 of the transformer.

[0057] Preferably, the above cited active filters contain substances of the Jeffamine family.

[0058] In practice it has been observed that the power and/or distribution transformer provided with on-load tap changer according to the invention fully achieves the intended aim and objects, since it can be nonflammable, non-explosive and compact, and furthermore, by way of the presence of suitable filters, free from any environmental impact.

[0059] The transformer thus conceived is susceptible

of numerous modifications and variations, all of which are within the scope of the inventive concept. All the details may also be replaced with other technically equivalent elements.

[0060] In practice, the materials employed, so long as they are compatible with the specific use, as well as the dimensions, may be any according to the requirements and to the state of the art.

[0061] Where technical features mentioned in any claim are followed by reference signs, those reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly, such reference signs do not have any limiting effect on the interpretation of each element identified by way of example by such reference signs.

Claims

1. A power and/or distribution transformer comprising:

   a) a tank provided with a magnetic core, high- and low-voltage windings, adjustment windings, insulating partitions made of solid material which are interposed between said high- and low-voltage windings and a dielectric and cooling fluid;
   b) an on-load tap changer which comprises:

      b.1)at least one selector which is immersed in a lubricating fluid;
      b.2)at least one diverter switch which comprises arc contacts and a dielectric arc quenching fluid;

   characterized in that the dielectric and cooling fluid of said transformer and/or the dielectric and arc-quenching fluid and/or the lubricating fluid of said selector are liquid perfluoropolyethers, and in that said tank and said diverter switch are each provided with a filter for reducing chemically reactive gas species generated by the decomposition of said fluids.

2. The transformer according to claim 1, characterized in that said fluids are perfluoropolyethers whose formula is:

   $$EndgroupA\text{-}O\text{-}(C_3F_6O)n\text{-}(CF_2O)m\text{-}EndgroupB$$

   $$EndgroupA\text{-}O\text{-}(C_2F_4O)n\text{-}(CF_2O)m\text{-}EndgroupB$$

   where EndgroupA and EndgroupB are mutually identical or different and are chosen between CF_3 and CF_2H.

3. The transformer according to claim 1, characterized in that said fluids have a viscosity of more than 1 cSt at room temperature.

4. The transformer according to claim 1, characterized in that the number of said insulating partitions made of solid material which are interposed between said high-voltage and low-voltage windings and the overall distance, through liquid only, between the high-voltage and low-voltage windings, given by the average distance D between the high-voltage and low-voltage windings minus the sum of the thicknesses of said insulating partitions, depends on the test voltage V* at industrial frequency of the transformer, according to the relation $NxD^* <= 5x(V^*)^2$, where D* is expressed in meters and V* is expressed in kilovolts, the above relation holding for V* >= 140 kV, and where D* is the total distance and N is the number of insulating partitions.

5. The transformer according to one or more of the preceding claims, characterized in that said on-load tap changer is partially contained in said tank, said selector of said tap changer being contained in said tank and being immersed in the dielectric and cooling fluid of said tank.

6. The transformer according to one or more of the claims from 1 to 4, characterized in that said tap changer is external with respect to the tank of the transformer.

7. The transformer according to one or more of the preceding claims, characterized in that said tank has, at its top, explosion-proof protection means which have a filter for reducing chemically reactive gas species generated by the decomposition of the dielectric and cooling fluid contained in said tank.

8. The transformer according to one or more of the preceding claims, characterized in that it comprises, at the top of the tank, a surge tank provided with an elastic sealing membrane in order to allow the thermal expansion of said dielectric and cooling fluid contained in said tank.

9. The transformer according to claim 8, characterized in that between said tank and said surge tank there is a gas protection device which is connected to gas collection means inside which there is a filter for reducing chemically reactive gas species generated by the decomposition of said dielectric and cooling fluid.

10. The transformer according to one or more of the preceding claims, characterized in that said tap changer has, at its top, an expansion device which allows the expansion of the dielectric arc-quenching

fluid contained in said diverter switch, which accommodates a filter for reducing chemically reactive gas species generated by the decomposition of said dielectric and cooling fluid.

11. The transformer according to claim 10, characterized in that between said diverter switch and said expansion device there are protection means which are connected to gas collection means which internally accommodate a filter for reducing the chemically reactive gas species generated by the decomposition of the dielectric arc-quenching fluid contained in the diverter switch of said tap changer.

12. The transformer according to one or more of the preceding claims, characterized in that each one of said filters contained in said explosion-proof protection means, in said gas protection device and in said protection means are filters which contain base compounds.

13. The transformer according to claim 12, characterized in that each one of said filters contained in said explosion-proof protection means, in said gas protection device and in said protection means are filters which contain substances of the Jeffamine family.

14. The transformer according to claim 12, characterized in that each one of said filters contained in said explosion-proof protection means, in said gas protection device and in said protection means are filters which contain soda-lime.

15. The transformer according to one or more of the preceding claims. characterized in that said dielectric arc-quenching fluid contained in said diverter switch of said tap changer is saturated with oxygen and is in contact with said expansion tank, the volume of which contains oxygen.

16. The transformer according to one or more of the preceding claims, characterized in that each one of said fluids has a moisture content of less than 10 ppm.

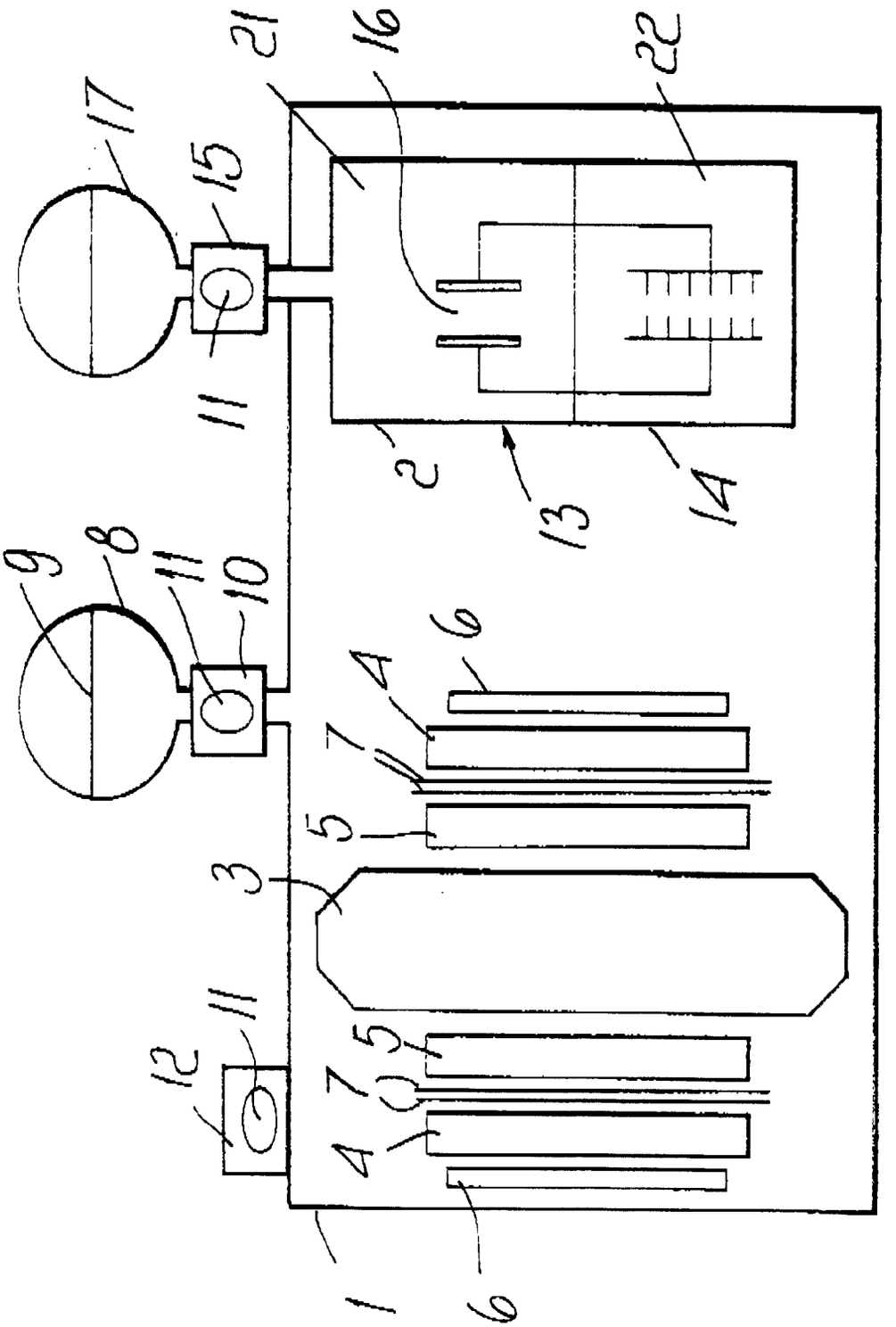

Fig. 1

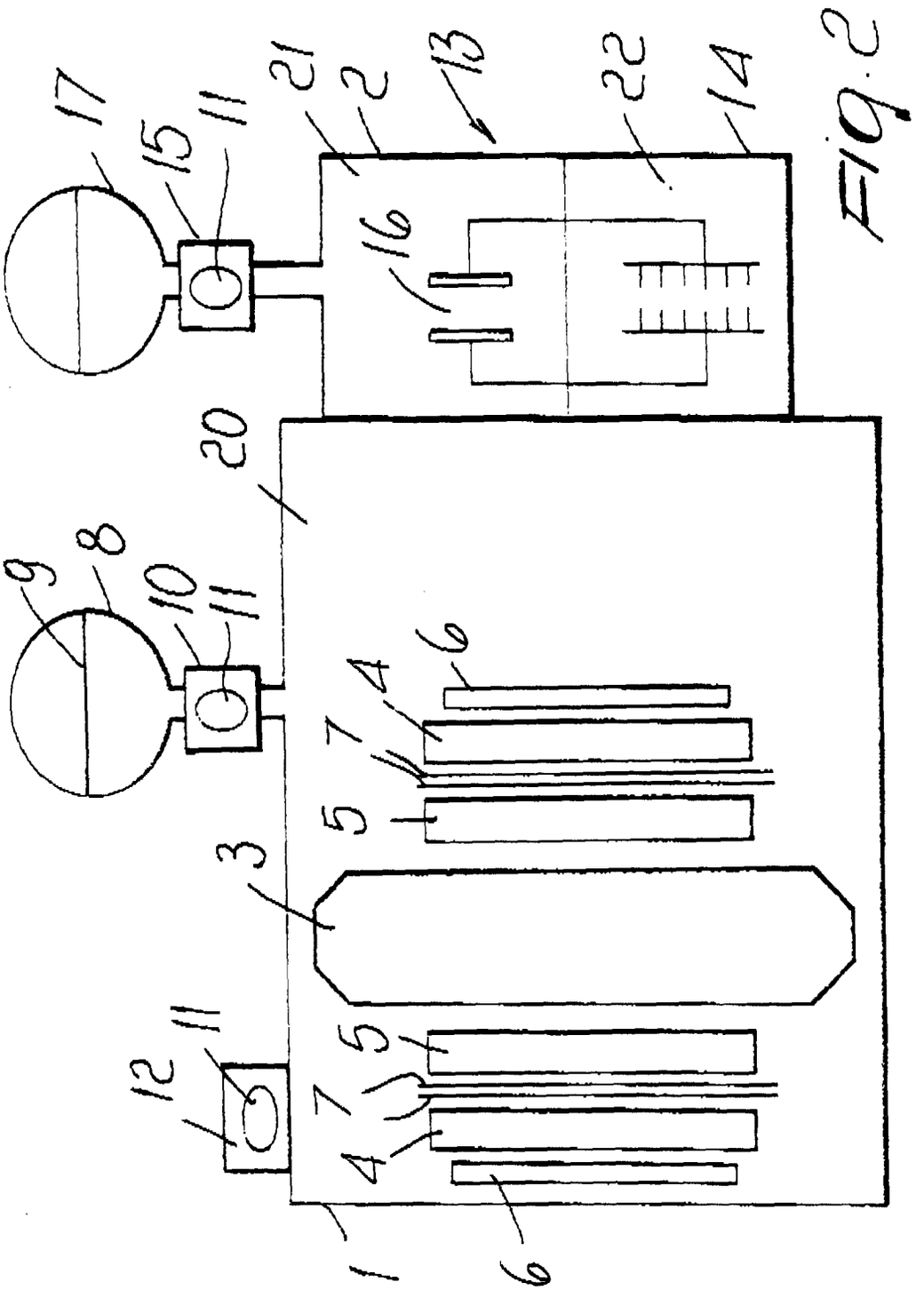

Fig. 2

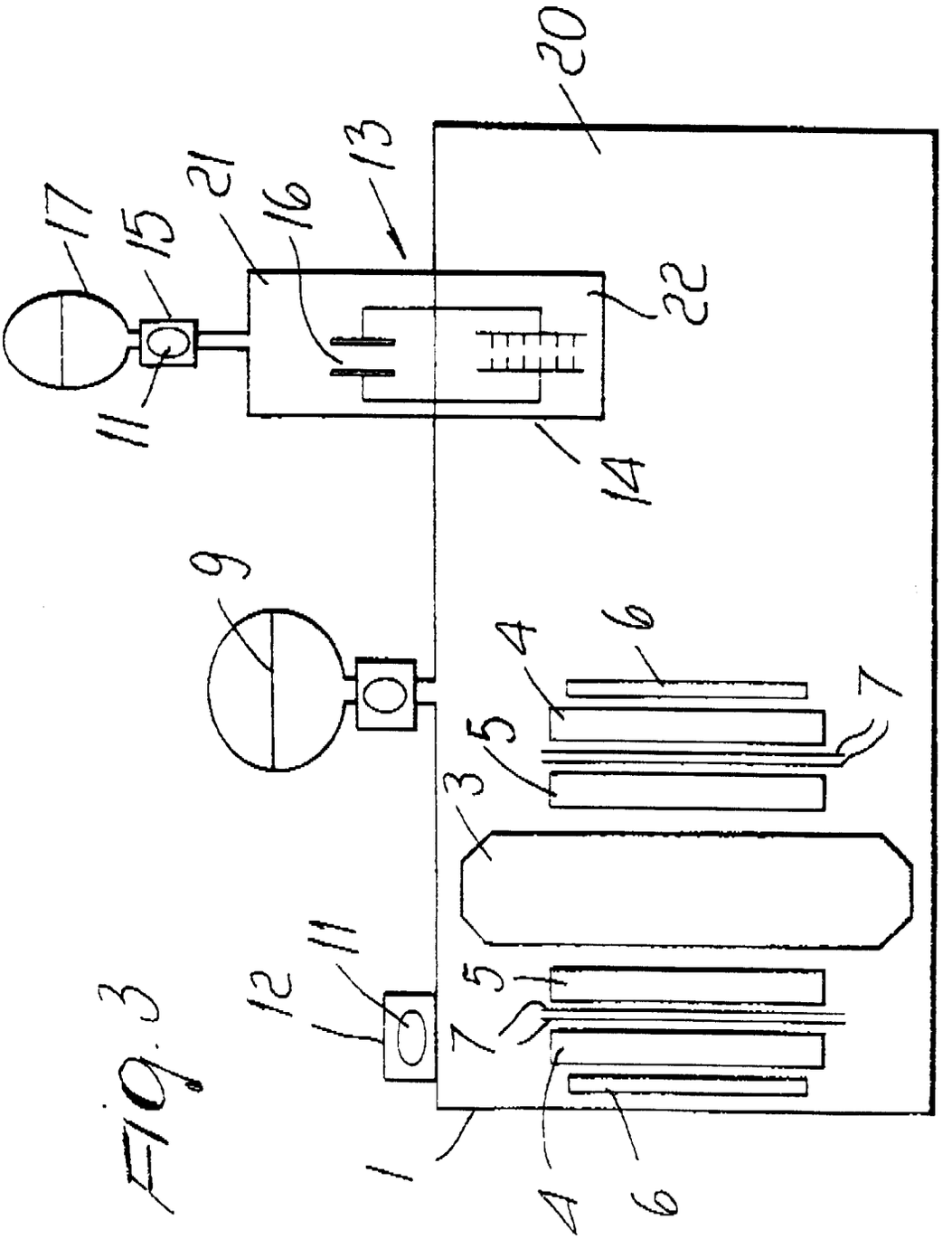

Fig. 3