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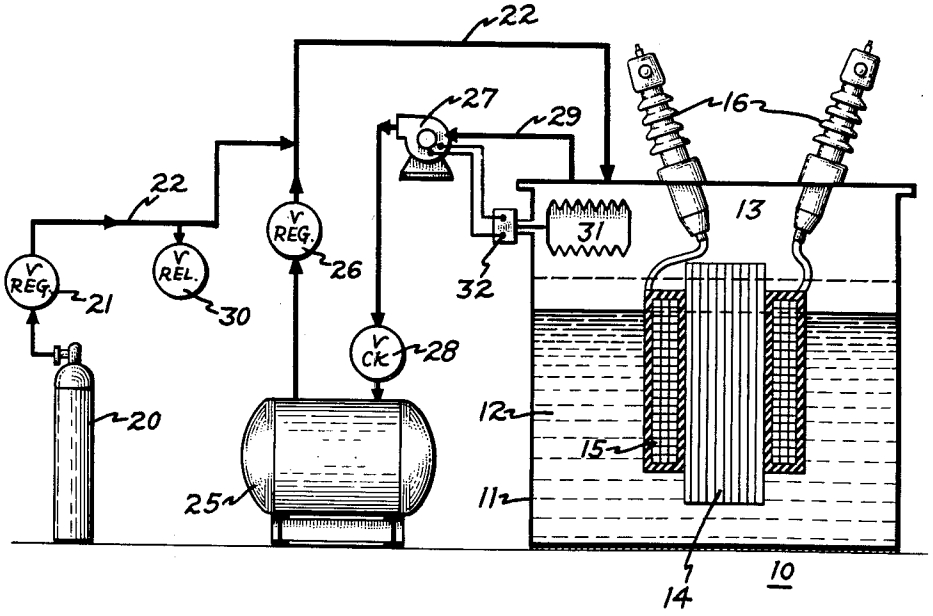

Inventors,
Herbert B. Detrick,
Kurt H. Weber,
by Gilbert P. Tarleton
Their Attorney.

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GAS BUBBLE PREVENTION SYSTEM FOR LIQUID INSULATED ELECTRICAL APPARATUS

Herbert B. Detrick, Pittsfield, Mass., and Kurt H. Weber, Shaker Heights, Ohio, assignors to General Electric Company, a corporation of New York

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6 Claims. (Cl. 174—12)

This invention relates to electrical apparatus, and more particularly to an improved means for preventing the formation of gas bubbles in the dielectric liquid of stationary electrical induction apparatus of the type having an electric device immersed in a dielectric liquid which is blanketed by a gas in a sealed container.

Stationary electrical induction apparauts, such as transformers or the like, are frequently immersed in a dielectric liquid, such as oil. In order to prevent contamination of the dielectric liquid by contact with air, the apparatus tanks are frequently sealed, and in order to allow for thermal expansion of the liquid in the tank, an inner gas space is provided within the tank contacting the liquid. As an example, a gas frequently employed in such capacity in electrical apparatus is nitrogen.

Where a gas and liquid are in such contact, some of the gas dissolves into the liquid, depending upon the kind of gas and liquid employed and the temperature and pressure of the fluids. The relationship between the amount of gas that dissolves in the liquid and the pressure of a gas may in some cases be a simple linear relationship. As an example, oil at 25° C. exposed to a nitrogen pressure of one atmosphere will dissolve 8.9% by volume of nitrogen, and when the nitrogen pressure is two atmospheres, the oil will dissolve 17.8% by volume of nitrogen.

If a closed system of transformer oil blanketed by nitrogen is given time to reach equilibrium at two atmospheres of pressure, so that the amount of nitrogen dissolved in the oil is 17.8% of the oil volume, and if the pressure is then released, for example, as a result of decrease in oil temperature in response to decrease in load, loss of excitation, or decrease in ambient temperature, the nitrogen will remain in the oil if the oil is undisturbed. The oil is then said to be in a supersaturated state, since the quantity of nitrogen exceeds the equilibrium quantity of 8.9% corresponding to its new environment at one atmosphere. If a sufficient time is permitted, the excessive nitrogen will diffuse out of the oil and eventually the system will restore itself to equilibrium corresponding to one atmosphere and 25° C., that is, 8.9% nitrogen by volume. This return to equilibrium may require an extended period of time, depending upon the surface to volume ratio of the oil and the amount of motion in the oil due to convection or other minor disturbances.

If the oil remains undisturbed, the gas will diffuse out of the oil in an orderly manner. There are several operating conditions, however, that can cause supersaturated oil to evolve gas in the form of gas bubbles throughout the oil. For example, such evolution of gas bubbles may arise from the agitation of oil by oil circulation pumps, the electrical shock of a transient voltage, or the mechanical shock of a short circuit. While the extent of supersaturation required to produce bubbles is dependent upon variables other than the extent of saturation, it has been found that, with nitrogen in transformer oil, bubble formation can be expected if the oil

is over saturated by 12% to 20%, i.e., when the pressure differential between gas in the oil and gas above the oil is between 2 and 3 pounds per square inch.

Due to the difference in dielectric constant and dielectric strength of nitrogen and oil, the formation of nitrogen bubbles in the oil has been found to reduce the dielectric strength of the oil by as much as two-thirds of its electrical strength without gas bubbles. Needless to say, this reduction of dielectric strength is highly undesirable, and may result in severe damage to or failure of the transformer.

In some instances a supply of gas, for example, from a pressurized cylinder of gas, is provided in order to maintain the pressure of the gas cushion within predetermined limits, since it has been found that substantial gas bubble evolution may occur if the range of pressures within the transformer tank is above about 2.5 p.s.i.g. In this type of system, which is known as the "automatic gas seal" type of oil preservation system, when the gas pressure reaches a maximum desired level the gas is vented to the atmosphere and when the pressure reaches a minimum level more gas is admitted to tank from the gas supply. While such a system may satisfactorily prevent evolution of gas bubbles if the range between the maximum and minimum pressures within the transformer tank is sufficiently narrow, the maintenance of such necessarily narrow limits may be highly undesirable due to the large quantities of gas that are normally expended in this type of oil preservation system as a result of periodic temperature cycling during operation of the transformer.

It is therefore an object of this invention to provide an improved system for the prevention of gas bubble evolution in electrical apparatus of the type having an electric device immersed in a dielectric liquid.

It is a further object of the invention to provide a gas bubble prevention system for maintaining a fluid pressure in electric apparatus of the type having electric device immersed in a dielectric liquid, the system maintaining the pressure in such apparatus within a sufficiently narrow range that evolution of gas bubbles in a liquid does not occur, and also not requiring the expenditure of excessive amounts of gas from a gas supply connected to a gas cushion in the apparatus.

Still another object of this invention is to provide a gas bubble prevention system for electrical apparatus of the type having an electrical device immersed in a dielectric fluid in a sealed tank and having a gas cushion contacting the liquid, the gas for said gas cushion being supplied from a pressurized gas supply, said system being characterized in that a narrow range of gas pressure is permitted in said gas cushion without the excessive expenditure of gas from the gas supply.

In accordance with one aspect of the invention, we provide means for preventing the evolution of gas bubbles in electrical apparatus of the type comprising a sealed enclosure containing a dielectric liquid in contact with a gas, and having an electric device immersed in the liquid. The means comprises storage tank means, means for withdrawing the gas from the enclosure to the storage tank means at a predetermined maximum enclosure pressure, and means for releasing gas from the storage tank to the enclosure, when the pressure in the enclosure is below a predetermined pressure which is less than the maximum desired pressure.

In the preferred arrangement of the invention, a supply of pressurized gas is provided to supply gas to the tank at a minimum pressure, and the gas is released from the storage tank to the enclosure at a pressure between the maximum pressure at which gas is withdrawn from the enclosure to the tank and the minimum pressure at which gas is supplied by the gas supply.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which we regard as our invention, it is believed that the invention will be better understood from the following description taken in connection with the accompanying drawing.

The single figure in the drawing illustrates a cross sectional view of a transformer and schematically shows the pressure regulation system of the invention as it may be connected to the transformer.

Referring now to the drawing, therein is illustrated an electrical apparatus such as a transformer **10** comprising a sealed tank **11** partially filled with a dielectric liquid **12** such as oil. A gas space **13** is provided in the upper portion of the tank **11**, to act as a cushion for volumetric changes in the oil **12**. The transformer core **14** and coils **15** are immersed in the dielectric liquid **12**, an external connection to the windings **15** is provided by way of bushings **16** mounted on and extending through the exterior walls or top of the tank **11**.

A supply of gas, such as pressurized gas cylinder **20**, is connected, by way of regulating valve **21** and conduit **22**, to supply gas at a predetermined minimum pressure to the gas space **13** in tank **11**. A gas storage tank **25** is also connected, by way of a regulating valve **26** and conduit **22**, to the gas space **13** of the apparatus tank **11**, and the storage tank **25** is also connected to the gas space **13**, by a separate path including a pump **27** and a check valve **28**. The pump **27** is arranged to withdraw gas from the gas space **13** through a conduit **29**, and the check valve **28** is arranged to prevent gas from flowing back through the pump **27** and conduit **29** to the gas space **13**. The regulating valves **21** and **26** are arranged to regulate the flow of gas respectively from cylinder **20** and storage tank **25** to the tank **11**. A relief valve **30** may be provided in the conduit **22**, for example, in order to relieve excessive pressures in the apparatus tank **11**.

A pressure responsive device, such as a bellows **31** is provided within the gas space **13**. The bellows **31** is mechanically coupled to suitable switching means **32** which is electrically connected to effect the energization of the pump **27** in response to the pressure in the gas space **13**.

During normal operation of the apparatus **10**, the temperature of the dielectric liquid **12** will vary depending, for example, upon the electrical load supplied by the apparatus and the atmospheric temperature. These temperature variations result in volumetric variation of the liquid, and, hence, variations in the pressure in the gas space **13**. The pressure responsive means **31** is adjusted to effect the energization of the pump **27**, by means of the switch means **32**, at a predetermined maximum pressure within the gas space **13**. When the pump **27** is energized, gas is withdrawn by way of the conduit **29**, pump **27** and check valve **28** to the storage tank **25**. The withdrawal of gas from the gas space **13** continues until the energization of the pump **27** is stopped in response to detection of a second predetermined pressure within the gas space **13** by the pressure responsive means **31**. The second predetermined pressure at which the operation of the pump ceases is of course lower than the maximum predetermined pressure at which the operation of the pump commences. The check valve **28** serves to prevent passage of the gas from the storage tank **25** back through the pump **27** and conduit **29** to the gas space **13**.

When the pressure in the gas space **13** drops below a third predetermined pressure (below the pressures at which the pump **27** is energized and de-energized) the regulating valve **26** opens to permit release of gas from the storage tank **25** to the gas space **13** by way of conduit **22**. The differential pressure between the maximum predetermined pressure and the pressure at which valve **26** opens is sufficiently narrow that gas bubble evolution will not occur in the apparatus.

If the pressure within the gas space **13** drops below a predetermined minimum value (less than the pressure of opening of the regulating valve **26**) such as may occur if insufficient gas is present in the storage tank **25**, the regulating valve **21** opens to permit release of gas from the pressurized gas cylinder **20** to the gas space **13** by way of the conduit **22**. The relief valve **30** may be set to relieve pressure in the gas space **13** at a predetermined pressure above the maximum desired operating pressure within the gas space.

As an example of typical settings of the valve and pressure responsive device to prevent evolution of gas in the liquid **12**, the pressure responsive means **31** may be set to energize the pump **27** at a pressure of 1.5 p.s.i.g. and de-energize the pump at a pressure of 1.0 p.s.i.g. The regulating valve **26** may be set to open when the pressure in the gas space **13** falls below 0.75 p.s.i.g., and the regulating valve **21** may be set to open when the gas pressure in the gas space **13** falls below 0.5 p.s.i.g. With these settings, the pressure in the gas space **13** is maintained between the pressures 0.5 p.s.i.g. and 1.5 p.s.i.g., a differential of one pound per square inch in pressure, which is sufficient to prevent the evolution of bubbles in the liquid **12**. The relief valve **30** may be set to relieve pressure in the gas space **13** at 2.5 p.s.i.g. in the event of sudden buildup of pressure in the tank **11**. It will be understood, of course, that the above example is purely illustrative, and other pressure settings of the valve and pressure responsive device may be employed to attain a desired pressure range within the gas space.

Since variations in the pressure in gas space **13** are compensated for by withdrawing gas to the tank **25** and releasing gas from the tank **25**, the present invention provides a fluid pressure regulating system having the advantages of the previously employed automatic gas seal type of oil preservation system without having the disadvantage of the large expenditure of gas resulting from pressure variations within the gas space **13**, and the expenditure of gas is not dependent upon the narrowness of range of pressures within the gas space.

It will be understood, of course, that while the form of the invention herein shown and described constitutes the preferred embodiment of the invention, it is not intended herein to illustrate all of the possible equivalent forms or ramifications thereof. It will also be understood that the words employed are words of description rather than of limitation, and that various changes may be made without departing from the spirit and scope of the invention herein disclosed, and it is aimed in the appended claims to cover all such changes as fall within the true spirit and scope of the invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. Means for preventing the evolution of gas bubbles in electrical apparatus of the type comprising a sealed enclosure containing a dielectric liquid in contact with a gas and an electric device immersed in said liquid, said means comprising storage tank means, pump means operatively connected between said tank means and enclosure to withdraw gas from said enclosure to said tank means when the pressure in said enclosure is between a predetermined maximum value and a second value, a check valve operatively connected between said tank means and pump means to prevent gas compressed in said tank means from flowing back through said pump to said sealed enclosure, and valve means operatively connected between said tank means and enclosure to release gas from said tank means to said enclosure when the pressure in said enclosure is below a predetermined value less than said predetermined maximum value.

2. Means for preventing the evolution of gas bubbles in electrical apparatus of the type comprising a sealed enclosure containing a dielectric liquid in contact with a gas and an electric device immersed in said liquid, said means comprising storage tank means, pump means connected to pump gas from said enclosure to said tank

means, means for detecting the fluid pressure within said enclosure, said pressure detecting means being connected to energize said pump means to withdraw gas from said enclosure when the pressure therein is between a predetermined maximum value and a second value, a check valve operatively connected between said tank means and pump means to prevent gas compressed in said tank means from flowing back through said pump to said sealed enclosure, and valve means operatively connected between said tank means and said enclosure to release gas to said enclosure when the pressure therein is below a predetermined value less than said predetermined maximum value, the differential between predetermined pressures being sufficiently narrow to prevent the evolution of gas bubbles in said liquid.

3. Means for preventing the evolution of gas bubbles in electrical apparatus of the type comprising a sealed enclosure containing a dielectric liquid in contact with a gas and an electric device immersed in said liquid, said means comprising storage tank means, pump means connected to pump gas from said enclosure to said tank means, means for detecting the fluid pressure within said enclosure, said detecting means being operatively connected to effect the energization of said pump means when the pressure within said enclosure reaches a first predetermined value and to continue the energization of said pump means until the pressure within said enclosure drops to a second predetermined value, means for preventing return flow of gas from said storage tank means to said enclosure through said pump means, and valve means connected between said tank means and enclosure to release gas from said tank to said enclosure when the pressure in said enclosure is below a third predetermined pressure less than said second predetermined pressure, the differential between said first and third predetermined pressures being sufficiently narrow to prevent the evolution of gas bubbles in said liquid.

4. Means for preventing evolution of gas bubbles in the dielectric liquid of electrical apparatus of the type having an electric device immersed in said liquid in a sealed enclosure, and in which said enclosure also contains a gas in contact with said liquid, said means comprising storage tank means, compressor means responsive to fluid pressure within said enclosure to pump gas from said enclosure to said tank to maintain the fluid pressure within said enclosure between a predetermined maximum value and a second value, means for preventing return flow of gas from said storage tank means to said sealed enclosure through said compressor means, and valve means responsive to fluid within said enclosure to release gas from said storage tank means to said enclosure to maintain the fluid pressure within said enclosure above a predetermined minimum value, the differential between said minimum and maximum pressures being sufficiently narrow to prevent the evolution of gas bubbles in said liquid.

5. An electrical transformer comprising a sealed enclosure containing a transformer core and winding coil, a dielectric liquid in contact with said core and winding partially filling said enclosure, a gas that is soluble in said liquid filling the remainder of said enclosure, means for preventing the evolution of gas bubbles in said liquid comprising a supply of pressurized gas connected to said enclosure, a gas storage tank, a compressor pump connected to said enclosure and storage tank to pump gas from said enclosure to said storage tank, means for detecting the fluid pressure within said enclosure, the pressure detecting means being connected to energize said compressor pump to withdraw gas from said enclosure when the pressure therein attains a pre-determined maximum value, a check valve operatively connected between said storage tank and compressor pump to prevent gas compressed in said storage tank from flowing back through said pump to said enclosure, a valve operatively connected between said supply of pressurized gas and said enclosure to release gas to said enclosure when the pressure therein is below a pre-determined minimum value less than said predetermined maximum value, and other valve operatively connected between said storage tank and enclosure to release gas from said storage tank to said enclosure when the pressure therein below a pre-determined value intermediate said maximum and minimum pre-determined values, the differential between the maximum and intermediate pressures being sufficiently narrow to prevent the evolution of gas bubbles in said liquid.

6. A transformer as recited in claim 5 in which said means for detecting the fluid pressure within said enclosure comprises a bellows located entirely within said enclosure and mechanically coupled to switching means which is electrically connected to effect the energization of said compressor pump.

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