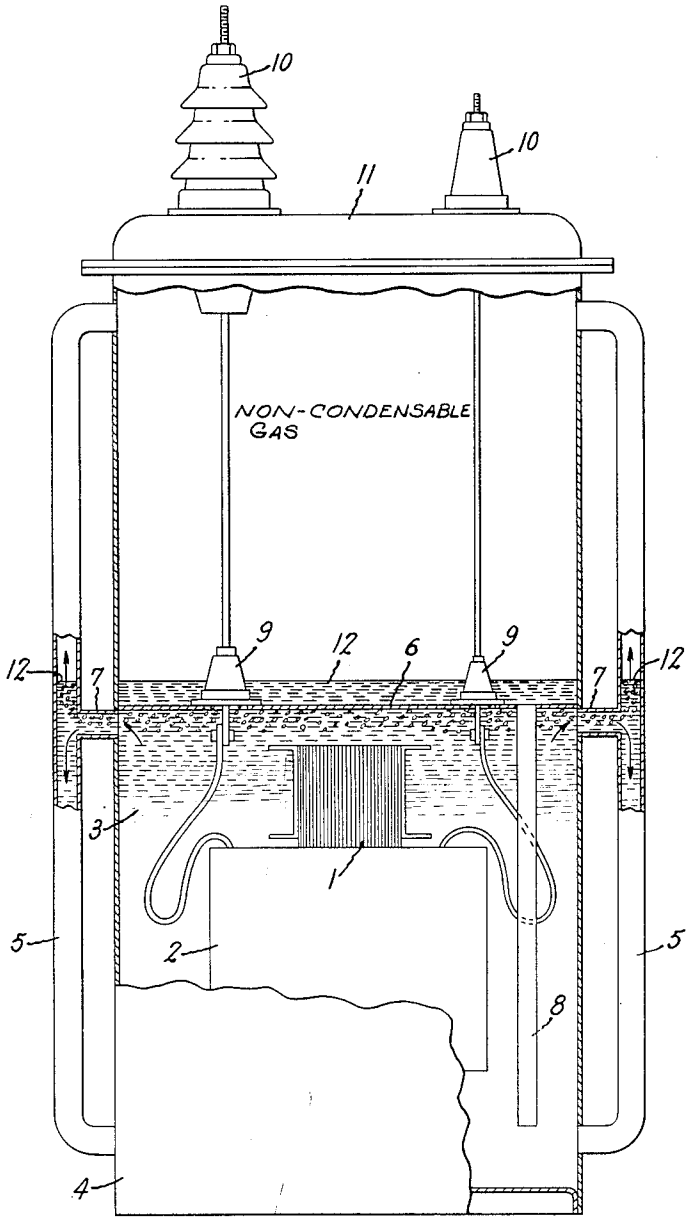
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VAPORIZATION-FORCED LIQUID COOLED TRANSFORMER

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VAPORIZATION-FORCED LIQUID COOLED TRANSFORMER

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This invention relates to stationary electrical induction apparatus, and more particularly, to an improved cooling system therefor.

In some types of stationary electrical induction apparatus the apparatus is placed within a tank that is nearly full with a dielectric and cooling liquid. When the apparatus is operating heat is produced. Natural convection is depended upon to remove some of this heat. That is, vertical radiating or cooling tubes are connected to the tank side walls. The warmest portion of the main body of liquid rises to the top thereof, passes into the radiating and cooling tubes, is cooled therein, and travels down the tubes back into the tank near the bottom thereof after which it can pick up more heat and repeat its cycle through the main body of liquid and radiating or cooling tubes. This cycle is not very rapid, consequently the heat that can be removed by natural convection is accordingly limited.

Above the surface of the liquid is an expansion space filled with an inert non-condensable gas. Some non-condensable gas is necessary in the system to maintain initial pressure to give initial dielectric strength. This expansion space is provided mainly for the increase in volume that the body of liquid undergoes when it is heated up. Practically no heat is removed by vaporization of the liquid and condensation of the vaporized liquid upon the cool side walls and top of the tank. This is due to the fact that dielectric liquids previously used were operated below their boiling points since they and the associated solid insulations would not usually give satisfactory life at the boiling point temperatures. Also, in any case the vapors and non-condensable gas within the expansion space become intermixed and the vapors do not have a very good opportunity to condense.

It is an object of this invention to provide an improved cooling system for a stationary electrical induction apparatus submerged within a dielectric liquid within a tank having radiators for circulating and cooling the liquid therein wherein the circulation of the liquid through said radiators is accelerated by self-actuated means.

It is a further object of this invention to provide an improved cooling system for a stationary electrical induction apparatus submerged within a dielectric and cooling fluid within a tank having radiating tubes, said fluid boiling at a temperature within the normal operating temperature range of said apparatus, whereby part of the heat produced by said apparatus is removed by vaporization and condensation of the dielectric fluid and circulation of the cooling fluid through the radiating tubes, and said circulation is accelerated by the vaporization phase of said cooling system.

It is a further object of this invention to provide an improved cooling arrangement for electrical apparatus submerged within a tank in a dielectric cooling liquid having radiating tubes for circulating and cooling said liquid, said liquid boiling at a temperature within the normal operating temperature range of said apparatus, wherein structure is provided for segregating the vapors of said liquid and a non-condensable gas located above the surface of said liquid whereby a greater amount of heat can be removed by vaporization and condensation of said liquid and wherein said structure and said vaporization cooling cooperates to increase the circulation of said liquid through said tubes.

My invention comprises a tank having a dielectric liquid and a stationary electrical apparatus submerged therein and vertical radiating tubes surrounding said tank for circulation of the liquid therein, said liquid having a boiling point temperature within the normal operating temperature range of said apparatus, and self-actuated means for increasing the circulation of said liquid through said tubes comprising a barrier positioned horizontally in said tank to divide said tank into a bottom liquid portion and upper gas portion, said tubes being connected by restricted passages with said bottom portion adjacent said baffle and a drain extending from said baffle to adjacent the bottom of said tank, said liquid when said apparatus is operating forming vapor bubbles therein, said vapor bubbles sweeping through said restricted passages at high velocity and carrying said liquid through said passages in percolator-like fashion, said liquid completely filling said bottom portion and partially filling said top portion and said tubes, and said vapor bubbles condensing in said tubes, a non-condensable gas located above the surface of said liquid, and said vapor bubbles sweeping said gas into said upper gas portion.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may be best understood by reference to the following description taken in connection with the accompanying drawing, in which there is shown a view of a stationary electrical induction apparatus or transformer embodying my improved cooling system.

In the drawing there is shown a stationary electrical induction apparatus or transformer comprising a magnetic core 1 and electrical windings 2 therefor. Said apparatus is submerged within a dielectric cooling liquid 3 within a tank 4. Vertical external cooling or radiating tubes 5 are connected to the tank 4 near the top and bottom thereof. A horizontal baffle or barrier plate 6 divides the tank into approximate equal halves, the bottom tank half being a liquid containing tank portion, and the top tank half being primarily a non-condensable gas containing tank portion.

Just below the baffle or barrier 6 restricted ducts or passages 7 connect the radiators or tubes 5 with the bottom portion or liquid half of the tank 4. A drain pipe 8 extends from the barrier 6 to closely adjacent the bottom of tank 4. As seen in the drawing, the liquid 3 completely fills the bottom half of the tank 4 and preferably partially fills the upper gas portion of the tank 4 and the tubes 5. The liquid 3 also fills the restricted passages or channels 7.

Above the surface level 12 of the liquid 3 is located an inert non-condensable gas. By a non-condensable gas I mean a gas that will not condense within the operating range of the transformer apparatus. Illustrations of such a gas are nitrogen or sulphur hexafluoride. This gas will partially fill the upper tank or gas container portion and the tubes 5.

Electrical leads extend from electrical windings 2 to bushings 9 insulatingly mounted on the barrier or baffle plate 6. The bushings 9 are sealingly mounted on the baffle plate 6 so that the liquid in the upper gas tank portion can reach the bottom tank portion only via the drain 8. Electrical leads also extend from the bushings 9 to bushings 10 insulatingly and sealingly mounted on

the cover 11 of the tank 4, bushings 10 providing electrical terminals for the transformer apparatus. However, if desired, the apparatus terminals could be located on the side walls of tank 4.

The operation of my improved cooling system will now be described. When the transformer apparatus is operating it becomes heated and this heat is transferred to the liquid 3. Some of the liquid 3 accordingly vaporizes. That is, vapor bubbles, as indicated in the drawing, are formed. These vapor bubbles rise to the top of the bottom half of the tank adjacent the baffle or plate 6 and have only restricted ducts or channels 7 through which to escape. Since the passages 7 are restricted or very narrow the vapor bubbles sweep therethrough at a relatively high velocity in a percolator-like fashion. That is, the high velocity vapor bubbles sweep some of the liquid 3 which is in the area of the baffle 6 and passages 7 through said passages. The arrows shown in the drawing and pointed towards and away from the passages 7 in a general way illustrate this action and the direction of flow or circulation of the vapor bubbles and the dielectric and cooling fluid 3. In a natural convection cooled stationary electrical induction apparatus the circulation of the cooling fluid through the radiating tubes or pipes is rather slow. The warmest portion of the cooling and dielectric liquid rises towards the surface thereof, enters the radiating tubes, is cooled therein, gravitates down the tubes, and reenters the main body of liquid in a cooler state where it can pick up heat and repeat its circulatory cooling cycle. In my invention, the baffle 6, restricted passages 7, and vaporization of the liquid 3 cooperate to accelerate this circulatory cooling cycle. Also, this acceleration is produced by self-actuating or natural means. No outside power is required to attain this increased circulation of the cooling fluid through the radiators or cooling tubes 5. Since the liquid vaporizes and the vapor bubbles gush through the restricted passages 7 carrying some of the liquid therewith this is in effect a vaporization-forced liquid cooled transformer.

After the vapor bubbles enter the tubes or cooling ducts 5 they rise through the surface level 12 of the liquid and move in a continuous and concentrated front up the tubes 5 pushing the non-condensable gas into the upper tank half or gas containing portion. Thus, intermixing of the vaporized liquid and the non-condensable gas is substantially prevented. This stream of rich concentrated vaporized liquid within the tubes 5, which is segregated from the non-condensable gas, condenses therein and then gravitates back down the ducts or pipes 5 into the main body of fluid where it can pick up heat again by being vaporized again. This condensed vapor, in passing down the ducts 5 of course is further cooled before reentering the main body of liquid within the bottom tank half. Some of the vapor bubbles rising in the radiating tubes 5 may not condense therein but may pass into the upper half of the tank along with the non-condensable gas. Such vapors will eventually condense therein along the cool side walls and cover 11 of the tank 4 and settle to the bottom of the upper tank portion. The drain 8 will carry these condensed vapors, now in the liquid state, back into the lower half of the tank where it can be re-vaporized. It should be noted that the drain 8 extends to near the bottom of the tank 4. This is so that the vapor bubbles formed in the liquid 3 will not pass directly into the upper gas containing tank portion but will be forced to seek their escape via small connecting portions 7 by gushing therethrough.

It should be noted that for the successful operation or utilization of my invention the dielectric and cooling liquid or medium 3 should have a boiling point temperature within the desired operating temperature range of the electrical apparatus. A variety of liquids can be used, amongst which are the freons and fluorocarbons, which are identified by the fact that they have boiling point temperatures within the normal operating temperature range of most electrical windings for stationary electrical apparatus.

Another important consideration in the efficient utilization of my invention is the dimensions of the restricted connectors or ducts 7. To obtain a vaporization-forced liquid cooled circulation obviously the ducts 7 must be small so that when the vapor bubbles pass therethrough the desired percolator-like action will be obtained wherein the vapor bubbles gushing therethrough will do so at high velocity and concomitantly sweep some of the dielectric liquid therethrough. If the ducts 7 are circular cross-sectioned tubes the inner diameter of said tubes may be in the range of about ½ to 2 inches for a medium size transformer of say 10 kva. rating. However, operating pressures, the size of the apparatus and hence the amount of losses to be dissipated, and how many tubes 5, 7 are present also affect the size of the restricted connectors 7. The more restricted the passages 7, the greater the velocity of the vapor bubbles therethrough and of the liquid carried along with the vapor bubbles. Also, if desired, there may be fewer of these passages 7 connected to a horizontal header or pipe to which each of the tubes 5 may be connected.

Some of the advantages of my improved cooling system will now be more clearly apparent. Since the latent heat of vaporization of most liquids is relatively high a cooling system which uses vaporization and condensation cooling of the cooling medium will obviously be capable of removing great quantities of heat if adequate cooling surfaces are provided. Also, if the circulation of the cooling medium within the external cooling pipes or tubes is increased this results in still a greater rate of heat removal. These two modes or phases of cooling are combined in a novel manner whereby the vaporization phase also serves to increase the circulation of the cooling medium at little additional cost. That is, no pumping is required for accelerated circulation of the cooling medium through the cooling pipes or tubes. Also, these two combined modes or phases of cooling are capable of removing a greater quantity of heat than can be removed by natural convection alone. This means that the operating temperature of apparatus embodying my invention is reduced. That is, the apparatus can be safely overloaded without danger of overheating. If the apparatus can be safely overloaded, then a smaller transformer unit will give the output of a larger unit. Thus, a saving in space and weight is also realized. In a conventional natural-convection cooled unit the surface liquid level would at least reach up to the uppermost point at which the vertical tubes are connected to the tank. My system requires less cooling and dielectric fluid, which also contributes towards a saving of weight.

While there has been shown and described a particular embodiment of the invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention, and that it is intended by the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

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

1. In an electrical apparatus submerged within a dielectric liquid within a closed tank having vertical radiating tubes for circulating the liquid therethrough, structure for accelerating the flow of said liquid through said tubes by natural means, said structure comprising a horizontal baffle extending to the side walls of said tank and dividing said tank into approximate equal isolated halves and a drain pipe extending from said baffle to adjacent the bottom of said tank, horizontally disposed restricted passage means adjacent the top of the tank bottom half

connecting said tubes and said bottom half, said liquid completely filling said bottom half with said apparatus submerged therein and partially filling the upper half of said tank and said tubes, said liquid having a boiling point temperature within the normal operating temperature range of said apparatus.

2. In an electrical apparatus submerged within a dielectric cooling liquid within a closed tank, said tank having a noncondensable gas therein above the surface of said liquid and vertical cooling radiators connected at opposite ends thereof adjacent the top and bottom of said tank, said liquid having a boiling point temperature within the normal operating temperature range of said apparatus whereby a substantial quantity of vapors are formed from said liquid during normal operation of said apparatus, means for segregating said vapors and non-condensable gas and causing said vapors to accelerate circulation of said liquid through said radiators comprising a horizontal baffle extending to all side walls of said tank and dividing said tank into approximately equal isolated upper and lower halves, said lower half and said radiators connected by horizontal ducts extending from substantially immediately below said baffle to central portions of said radiators, said lower half completely filled with said liquid and said upper half having a minimum of said liquid therein whereby approximately only the lower halves of said radiators are filled with said liquid, a drain extending from said baffle to adjacent the bottom of said tank, and said apparatus positioned in said lower half.

3. In an electrical apparatus which is submerged within a dielectric liquid within a closed tank, said liquid having a boiling point temperature within the normal operating temperature range of said apparatus, a vertically disposed condensing and cooling radiator for said liquid, the lower end of said radiator being connected to said tank adjacent the bottom thereof, a baffle located in said tank adjacent and below the surface of said liquid, and a duct extending from said tank adjacent to and below said baffle to a central portion of said radiator.

4. In an electrical apparatus submerged within a dielectric and cooling liquid within a closed tank having vertical radiating tubes for circulating and cooling said fluid by natural convection, said liquid having a boiling point temperature within the normal operating temperature range of said apparatus, means for increasing the circulation of said liquid through said tubes comprising a horizontal barrier extending to the side walls of said tank and dividing said tank into approximate equal halves, a drain extending from said barrier to adjacent the bottom of the bottom tank half, said bottom half being full of said dielectric liquid and said apparatus located therein, and restricted ducts connecting said bottom tank half with said tubes adjacent a central portion of said tubes.

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