March 6, 1962 C. E. GOLTSOS ET AL 3,024,298

EVAPORATIVE-GRAVITY COOLING SYSTEMS

Filed July 10, 1958

2 Sheets-Sheet 1

FIG. 1

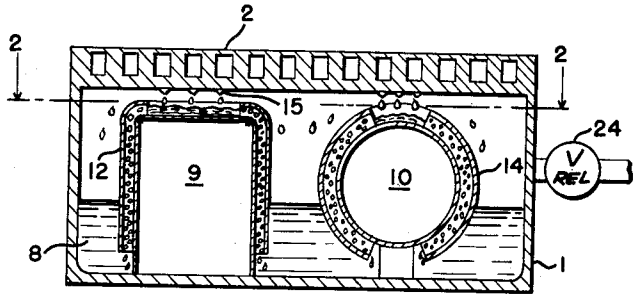


FIG. 2

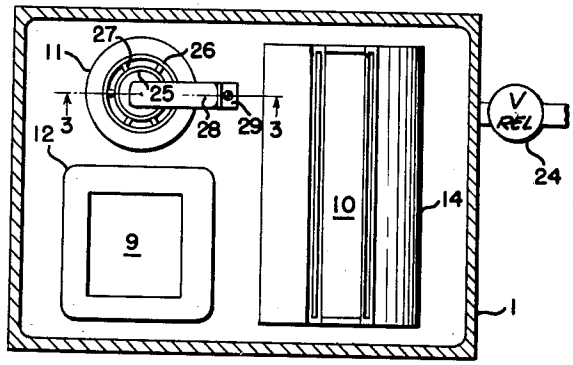
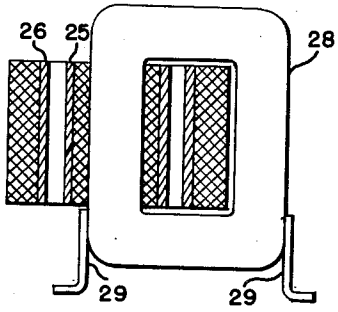


FIG. 3



INVENTORS

COSTAS E. GOLTSOS
MELVIN MARK
MARK E. STEVENSON, JR.

BY A Vincent Harsha

ATTORNEY

March 6, 1962 C. E. GOLTSOS ET AL 3,024,298

EVAPORATIVE-GRAVITY COOLING SYSTEMS

Filed July 10, 1958

2 Sheets-Sheet 2

FIG. 4

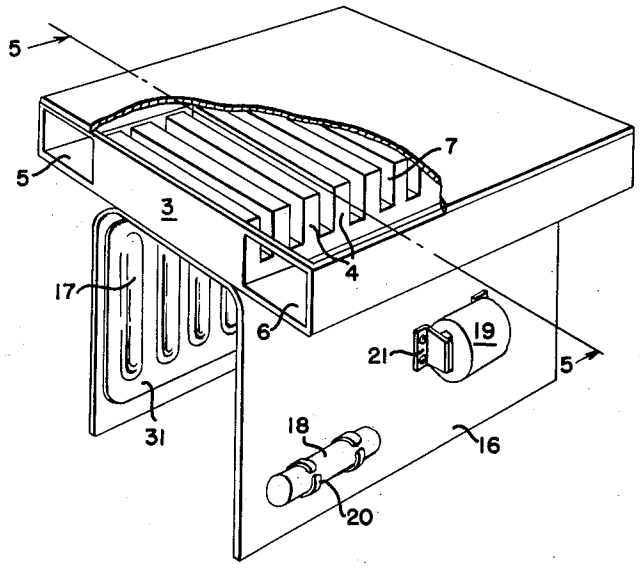
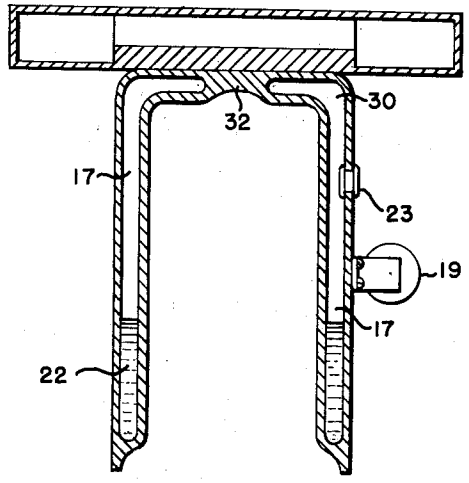


FIG. 5



INVENTORS

COSTAS E. GOLTSOS
MELVIN MARK
MARK E. STEVENSON, JR

BY N. Vincent Haraka

ATTORNEY

United States Patent Office 3,024,298 Patented Mar. 6, 1962

3,024,298

EVAPORATIVE-GRAVITY COOLING SYSTEMS

Costas E. Goltsos, Auburndale, Melvin Mark, Waban, and Mark E. Stephenson, Jr., Cambridge, Mass., assignors to Raytheon Company, a corporation of Delaware

Filed July 10, 1958, Ser. No. 747,656
5 Claims. (Cl. 174—15)

The invention relates in general to light weight, compact cooling systems and more particularly relates to a system for transferring heat from heat generating components in an electrical or electronic device which requires less liquid than is required in the usual oil bath in which such components customarily are immersed.

The system here disclosed employs simple evaporation of a liquid and condensation of the vapor to transfer heat from components to a heat exchanger instead of the conventional oil bath or metal heat conduction paths between components and heat exchanger. The heat transfer fluid employed is preferably a Freon refrigerant or fluorochemical but the fluid does not perform in the familiar refrigeration role. Instead heat from the components causes the liquid to vaporize, carrying off heat. The vapor rises under its own pressure and is so confined that as it rises it pushes some liquid to a higher level. Through this pumping action or "percolation," liquid is lifted above the free liquid level of the refrigerant and vaporization occurs from heated surfaces above the free liquid level. This eliminates the need for providing a free liquid level which is up to the tallest component, thereby reducing the amount of liquid required in the system. With this system, the higher the heat density, the more violently the liquid boils and the more effective the percolation effect becomes. The vapor which rises is caused to condense on a heat exchanger and the condensate drips down into the refrigerant pool below. The process involved is not a conventional refrigeration cycle, and no pump is required to compress the working substance. The flow of refrigerant is of the gravity return-type, the motive power inducing the flow being derived from the heat being dissipated. As this heat is waste energy, no power penalty is involved in circulating the working substance.

In order to utilize best an evaporative, gravity-return system, heat dissipating components should have liquid refrigerant in contact with their surfaces. This avoids unequal surface temperature distribution and hot spots, but in the past this has presupposed filling the container to at least the level of the tallest component to be cooled. Because of the high density of most of the suitable refrigerants, the weight of the refrigerant is a considerable factor and it is the purpose of the invention to reduce the quantity of refrigerant without degrading the performance of the cooling system.

The invention resides in an evaporative-gravity cooling system in which vaporized liquid is caused to follow a confined path so that liquid is trapped ahead of the vapor and is lifted as the bubbles of vapor rise. In one embodiment of the invention the vapor is caused to condense on a cold plate situated above the heat dissipating components so that the condensate drips down upon the heat generating components. Another embodiment of the invention permits the heat generating components to be mounted in accessible locations outside the closed cooling system.

The features of the invention which are believed to be novel are set forth with particularity in the appended claims. The invention, both as to its organization and method of operation, may best be understood by reference to the following detailed description when considered in connection with the accompanying drawing in which:

FIG. 1 is an elevational view of one embodiment of the

invention in which the casing has been broken away to permit a view of its interior;

FIG. 2 is a top view taken along the line 2—2 of FIG. 1;

FIG. 3 is a sectional view taken along the line 3—3 of FIG. 1 of a transformer constructed to permit percolation of a fluid through its windings;

FIG. 4 is a perspective view of another embodiment of the invention having exteriorly mounted heat dissipating components; and

FIG. 5 is an elevational view of a section taken along the line 5—5 of FIG. 4.

Referring now to FIG. 1, there is shown a hermetically sealed casing **1** having its top wall formed by a heat exchanger **2**. The heat exchanger **2** is similar in construction to the heat exchanger **3** shown in FIG. 4 which is formed by spaced fins **4** enclosed within a duct having an air inlet passage **5** and an air outlet passage **6**. Air entering the inlet passage is constrained to flow in the channels **7** between the fins, thereby cooling the latter. The air in the casing **1** is first withdrawn by means of a vacuum pump and then a sufficient charge of refrigerant **8** is introduced into the casing to bring the level up to the desired height. Part of the liquid refrigerant will evaporate until the vapor pressure in the system is at a pressure corresponding to its environmental temperature, which may be determined by the pressure-temperature relationship for the substance used. Fluorochemical refrigerants because of their dielectric and chemical properties, generally allow immersion of electrical parts directly in the fluid. A fluorochemical having the formula $C_8F_{16}O$ and bearing the trade designation FC–75 of the Minnesota Mining and Manufacturing Company has been found to be suitable for immersion of electrical components. Because the dielectric strength of suitable fluorochemicals and Freons, both in the liquid and vapor states, is better than the dielectric strength of air at atmospheric pressure, closer spacing of components having high electrical potential differences is permissible whereby a smaller package is attained. Completely enclosed in the chamber formed by the casing **1** and secured to its floor by any suitable means (not illustrated) are heat generating components here indicated by a transformer **9**, a motor **10**, and a second transformer **11**. The transformer **11** is constructed so that spaces are provided between turns of the windings to permit the refrigerant to percolate therethrough; that is, the windings may be considered to be formed by concentric sections separated by percolation spaces. In order to maintain the spacing between sections, a form comprising two concentric cylinders **25**, **26** separated by ribs **27** may be employed. A vertical sectional view through the transformer **11** is shown in FIG. 3. One section of the windings is wrapped around a leg of a rectangular iron core **28**, the cylinders **25**, **26** are fitted about the inner section and the outer section of the windings is wrapped about the outer cylinder. The core **28** is provided with dependent mounting brackets **29** which are secured to the floor of the casing. Surrounding each of the heat generating components **9** and **10** is a baffle contoured to fit thereabout and having ribs for maintaining a "percolation" space through which the liquid refrigerant can pass. The baffles may be secured to their associated components in various ways. For example, the baffle **14** surrounding the motor **10** may be cast integrally with the housing of the motor and the baffle **12** surrounding the transformer **9** may be simply forced down over the transformer's housing so that the ribs pinch the walls of the housing. The baffles are so constructed that the "percolation" spaces are open at the bottom to admit liquid refrigerant and are open at the top to permit vapor to rise toward the heat exchanger. As the components **9**, **10**, and **11** become heated during

operation, they will cause the refrigerant to boil so that vapor formed in the "percolation" spaces will rise as bubbles, pushing ahead the entrained liquid which will be carried to the top of the heated components. As the entrained liquid flows by the upper surfaces of the components it will absorb heat and become vaporized thereby cooling those upper surfaces. Once free of the baffles the vapor will continue to rise until the heat exchanger, which forms the cover of the casing, is encountered. The vapor will then condense upon the interior surface of the heat exchanger 2 and drip down into the pool of liquid refrigerant or drop upon the components. To insure the condensate dripping over the components the interior surface of the heat exchanger, otherwise known as a cold plate, may be provided with pimples or stalactites 15 situated over the components so that droplets of condensate form thereon.

A second embodiment of the invention is illustrated in FIGS. 4 and 5 which may be employed where the heat dissipating components must remain accessible or where the components cannot be immersed in a liquid. As shown in the latter figures, the casing 16 is a U-shaped member having interior passages 17. The bight of the U is brazed or otherwise secured to a heat exchanger 3 having spaced fins 4 defining channels 7 through which a cooling medium such as air is forced to circulate. The passages 17 of the casing 16 are first evacuated and an appropriate charge of liquid refrigerant is introduced. The liquid refrigerant 22 only partially fills the passages 17. The heat dissipating components, here indicated by a resistor 18 and a transformer 19, are secured to the sidewalls of the casing by suitable means such as the clamps 20 and brackets 21. After the refrigerant commences to boil, bubbles of vapor rise in the constricted passages causing some of the liquid to become entrained and be pushed upwardly toward the heat exchanger 3. When the vapor reaches the bight it condenses due to the removal of its heat by the heat exchanger and the condensate drips down into the passages. It is desirable to fasten those components generating large quantities of heat below the free liquid level in the passages 17 and to secure those components generating lesser quantities of heat above the free liquid level. Since heat conduction to the fluid in the passages is made through the walls of the casing 16, it is also desirable to have large contacting surfaces between the components and the casing's walls. Communication between the vertical passages 17 is effected by means of horizontal channels 30 and 31 so that the free level of the liquid will be equalized in all the vertical passages. The vertical passages 17 must be of sufficient cross sectional area so that the vaporized refrigerant does not prevent the condensate from returning to the pool below. If the cross-sectional area of the vertical passages 17 is too small there is a likelihood that liquid may be trapped in the upper regions of the passages by the vapor formed below. While heat generating components are shown to be secured to only one side of the casing 16 in FIGS. 4 and 5, it is to be understood that both sides of the casing 16 may be utilized for the attachment of components. The partition 32 in the center of the bight of casing 16 is provided to prevent all the liquid from being pumped by percolation from one side of the casing to the other. Each half of the casing 16, therefore, forms an independent closed refrigerating system.

Since the evaporative system is completely closed, the pressure inside the system will increase as the refrigerant vaporizes and if the heat exchanger cannot carry off the heat at an adequate rate, a rise in temperature will ensue, causing an inordinate rise in pressure within the system. To safeguard against explosion of the casing, a safety plug 23 is provided in the wall of the casing 16 which will be blown out when the interior pressure exceeds a predetermined value. In lieu of a blow out plug, a safety valve, such as the valve 24 in FIG. 1, may be employed to vent the interior of the casing when the pressure exceeds a safe value. The safety valve is preferable to a blow out plug because the entire charge of refrigerant is not lost by a safety valve as such valves are constructed to close when the pressure is reduced to a safe value. With a blow out plug, however, the entire charge of refrigerant will ultimately be lost.

It is apparent that other embodiments of the invention may be made and that modifications of the apparatus described above and illustrated in the drawings can be effected without departing from the essence of applicant's concepts. It is intended, therefore, that all matter contained in the description and shown in the accompanying drawings shall be deemed to be exemplary only and that the scope of the invention be defined by the claims herein.

What is claimed is:

1. An evaporative-gravity cooling system comprising a casing defining a totally enclosed chamber, heat dissipating components secured to said casing, a liquid refrigerant partially filling said chamber, the free level of said liquid refrigerant being substantially below the top level of said heat dissipating components said chamber having constricted passages therein permitting said liquid when boiling to percolate therethrough, whereby said liquid vaporizes above the free liquid level, a heat exchanger having a cooling surface situated at the top of said chamber, the vaporized liquid thereby condensing on said cooling surface, said heat exchanger including exterior cooling fins, and means for circulating a cooling medium over said fins.

2. An evaporative-gravity cooling system comprising a casing defining a totally enclosed chamber, a liquid refrigerant partially filling said chamber, a heat dissipating component positioned in said chamber, said component being partially immersed in said refrigerant so that the free level of said liquid refrigerant is substantially below the top level of said heat dissipating component, a baffle surrounding said component and spaced therefrom to define a percolation space, said baffle being partially immersed in said refrigerant, whereby a portion of said refrigerant rises in said baffle and vaporizes above the free level of said liquid refrigerant, a heat exchanger forming the upper wall of said casing, said heat exchanger having exterior fins, and ducting enclosing said fins to cause a cooling medium to flow over said fins.

3. An evaporative-gravity cooling system comprising a metallic casing having enclosed constricted vertical passages therein, a liquid refrigerant partially filling said passages, heat dissipating components secured to the exterior wall of said casing whereby heat is transferred through said wall to said refrigerant to cause said refrigerant to boil and to percolate upwardly through said constricted passages, the free level of said liquid refrigerant being substantially below the top level of said heat dissipating components, whereby the percolated refrigerant present in said constricted passage vaporizes above the free level of said liquid refrigerant a heat exchanger situated at the top of said vertical passages whereby the vaporized refrigerant is caused to condense, said heat exchanger having cooling fins, and ducting enclosing said fins whereby a cooling medium is constrained to flow over said fins.

4. An evaporative cooling system comprising a casing defining a totally enclosed chamber, a liquid refrigerant partially filling said chamber, a transformer situated in said chamber and partially immersed in said liquid refrigerant so that the free level of said liquid refrigerant is substantially below the top level of said transformer, the windings of said transformer being separated to define percolation spaces, means mounting said transformer to permit said refrigerant to enter said spaces to percolate therethrough, whereby the refrigerant present in said spaces vaporizes above the free level of said liquid refrigerant, a heat exchanger forming the upper wall of said

casing on which vaporized refrigerant condenses, and means for removing heat from said exchanger.

5. An evaporative-gravity cooling system comprising a casing defining a totally enclosed chamber, a liquid refrigerant partially filling said chamber, a transformer positioned in said chamber and partially immersed in said refrigerant so that the free level of said liquid refrigerant is substantially below the top level of said transformer, the windings of said transformer being separated to define vertical percolation spaces, means mounting said transformer permitting liquid refrigerant to enter said percolation spaces at the bottom thereof and vapor to issue from the top thereof, a heat exchanger forming the upper wall of said casing on which vaporized refrigerant condenses, and means for removing heat from said heat exchanger.

References Cited in the file of this patent

UNITED STATES PATENTS

2,083,611	Marshall	June 15, 1937
2,112,733	Burnham	Mar. 29, 1938
2,642,046	Alexander	June 16, 1953
2,643,282	Greene	June 23, 1953
2,748,356	Kaehni	May 29, 1956
2,872,651	Treanor	Feb. 3, 1959

FOREIGN PATENTS

871,723	France	Jan. 19, 1942