

Dec. 4, 1962

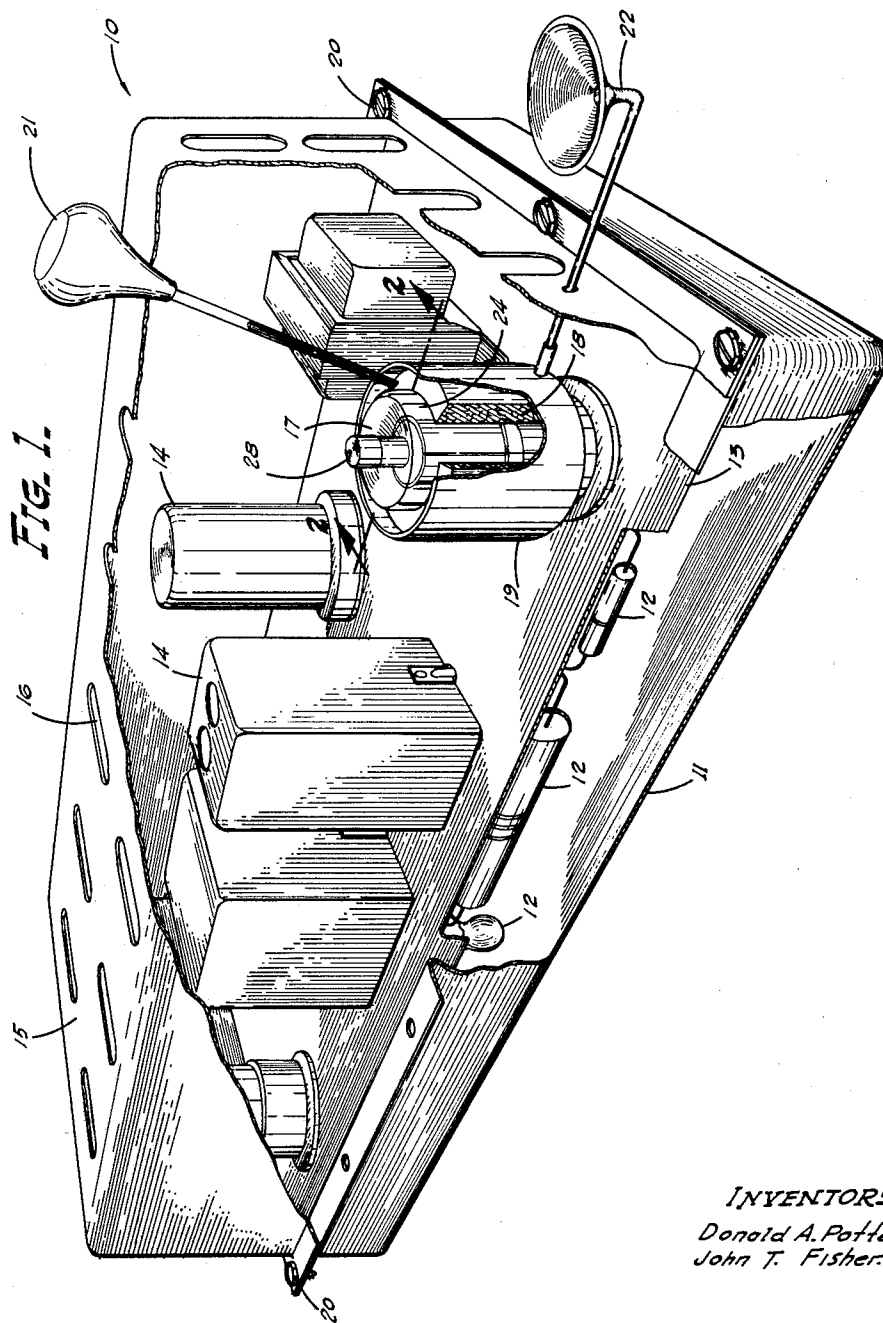
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3,066,499

ELECTRONIC COOLING BY WICK BOILING AND EVAPORATION

Filed Jan. 2, 1959

5 Sheets-Sheet 1



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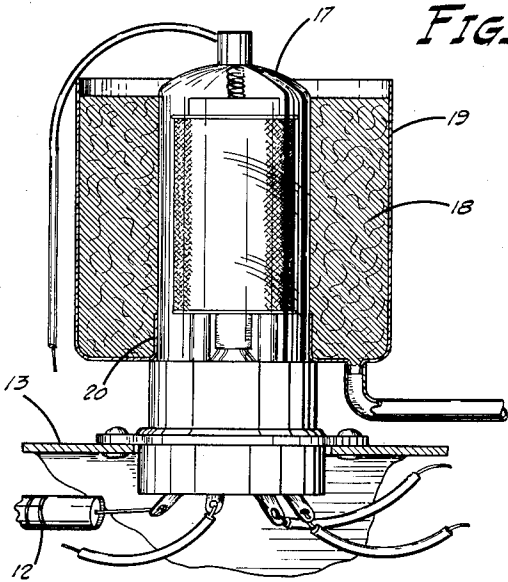
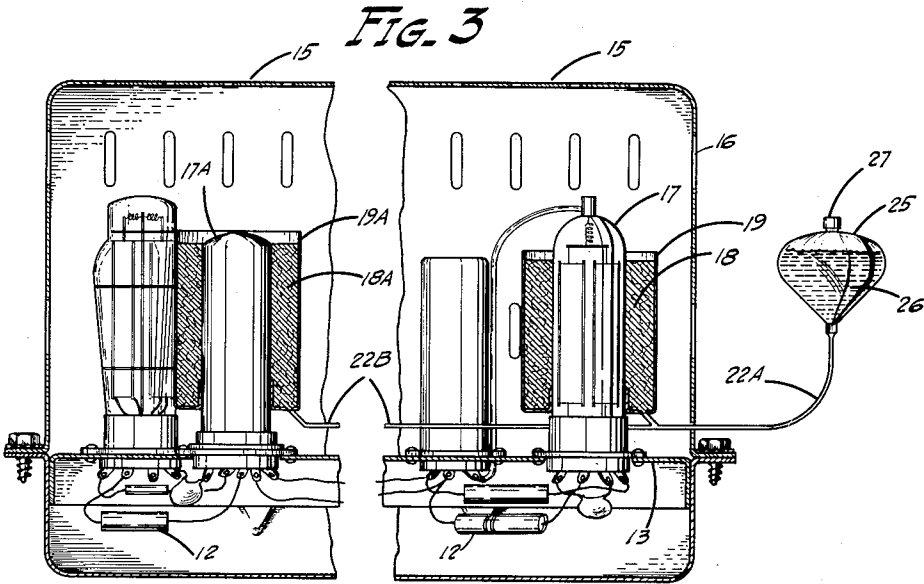
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FIG. 4

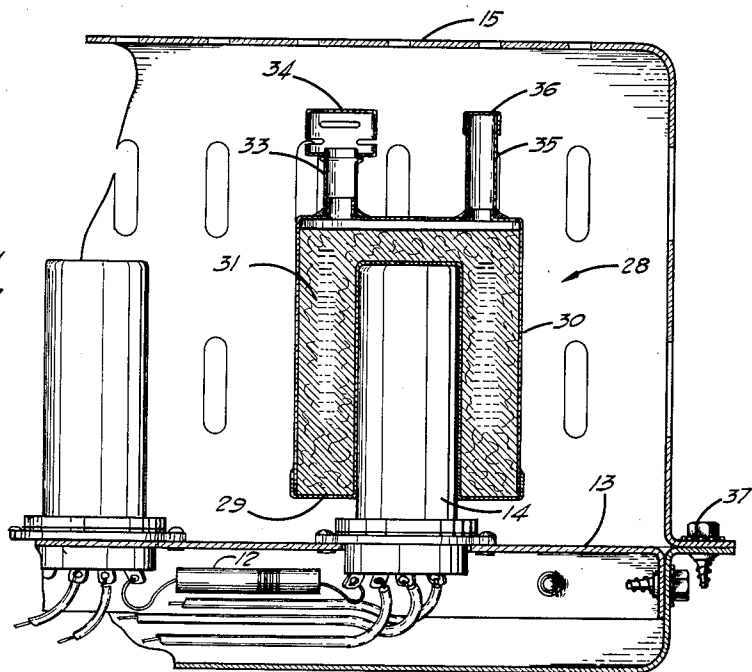
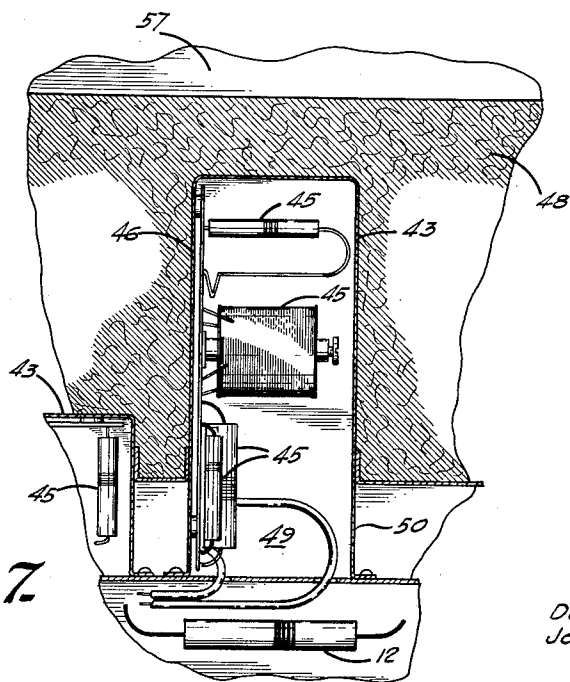


FIG. 7



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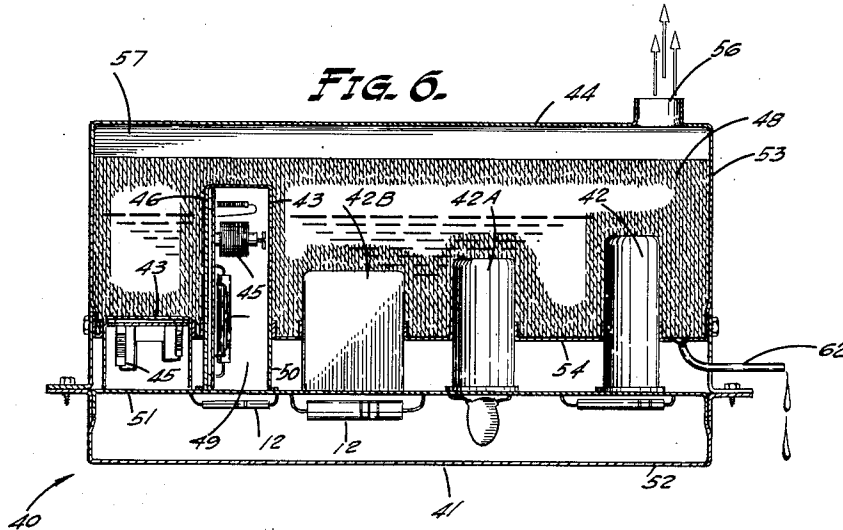
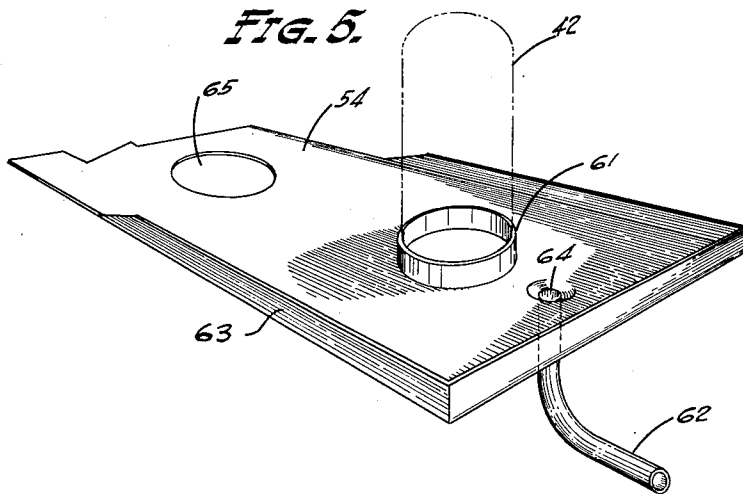
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5 Sheets-Sheet 4



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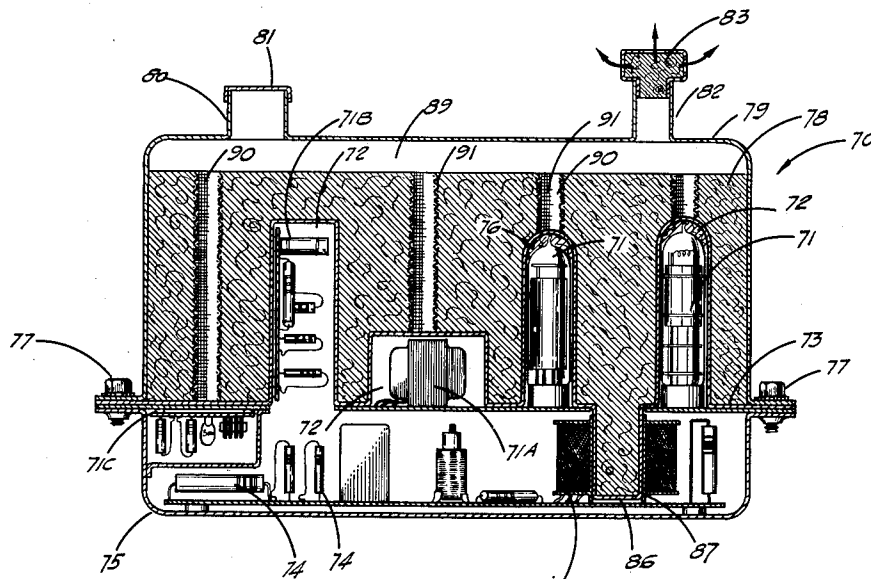


FIG. 8.

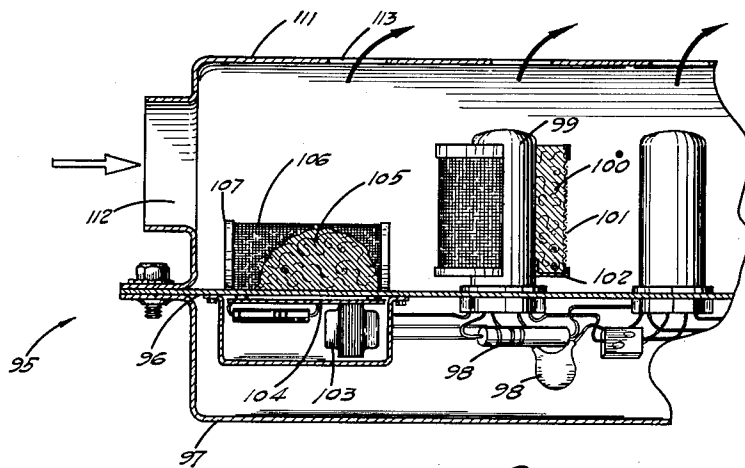


FIG. 9.

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## ELECTRONIC COOLING BY WICK BOILING AND EVAPORATION

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4 Claims. (Cl. 62-316)

This invention relates to cooling of electronic equip-  
ment by wick boiling and evaporation and more particu-  
larly to a wick cooled electrical component.

In electronic equipment of the prior art in which  
liquid is used for cooling employing the submerged or  
pool boiling principal, it is necessary to fix the equipment  
in a stationary position in order to keep the liquid in  
its proper place, or as an alternative complicated means  
must be provided to contain the liquid and at the same  
time enable the resulting vapor formed from any boil-  
ing coolant to escape to the atmosphere. Some electronic  
units employ complex vent or check valves which permit  
one side or the top of the unit to be open to atmosphere,  
while the other sides and bottom remain closed to pre-  
vent loss of the liquid coolant. This type of exchanger  
requires means for closing one or more of the valves  
should the exchanger be turned on the side or its top,  
and means for opening one or more of the valves to per-  
mit escape of vapor to the atmosphere. Other prior art  
electronic units employ a reservoir sufficiently large so  
that a vent pipe extending approximately into the middle  
of this reservoir is always above the level of liquid re-  
gardless of the attitude of the exchanger. Obviously, if  
the exchanger is inverted, the liquid coolant is at best in  
contact with only a portion of the heat exchange sur-  
faces. This mode of operation reduces the cooling of  
the liquid exchanger during those periods in which all or  
part of the liquid is not in contact with the heat ex-  
change surfaces, as well as being complex in structure.

The prior art electronic equipment employing cooling  
of this type cools the entire unit or a major portion of  
the unit, because it has a reservoir for containing the  
water of sufficient size to hold the required quantity of  
liquid. This reservoir, therefore, extends over a large  
portion of the electronic unit. This arrangement makes it  
difficult if not impossible to selectively cool one or more  
of the units which require cooling while the balance do  
not. Additionally, electronic units which employ sub-  
merged boiling or evaporation and which have a reservoir  
to contain the liquid coolant must employ a leakproof  
reservoir to prevent spillage to the outside or to the  
electronic chassis.

An object of the invention is to provide equipment  
having a plate member having wetted wick material on  
one side and an electrical component on the other side  
thereof.

Another object of this invention as applied to electronic  
equipments is to retain the coolant liquid against the hot  
portions of an electronic chassis with the electronic unit in  
any attitude through the use of a simple construction  
employing a wick and not necessarily requiring valves or  
baffles.

Another object is to provide in an electronic chassis  
a simple and reliable wick means for distributing to the  
hot surfaces a liquid coolant from a storage reservoir.  
The liquid is carried from this storage reservoir and dis-  
tributed to the hot surfaces by wick action.

Another object is to reduce the weight and size of an  
electronic chassis in which cooling is necessary and at the  
same time maintain a high heat exchange efficiency by  
using a wick to bring the least amount of liquid in con-  
tact with the heat exchange surface required to establish  
a uniform wetting thereof.

Another object is to provide means for placing a liquid  
coolant directly against the hot surface of the electronic  
component to be cooled rather than employing an inter-  
mediate liquid type wall which is necessary in prior art  
devices to prevent spillage of the liquid coolant.

A preferred embodiment of the electronic cooling ap-  
paratus of this invention employs a wall member with  
wetted wick material on one side and electrical and/or  
electronic components on the other side thereof. The  
wall member comprises a chassis having recesses for the  
components and other electrical components not requir-  
ing so heavy cooling as those in the recesses may be  
mounted on the component side of the chassis. Those  
units which are not enclosed within the recesses in the  
chassis may be protected by a cover. Also, the electrical  
or electronic unit which requires cooling may be sur-  
rounded by a sheath having wetted wick material there-  
around.

The wick material may communicate with a source of  
liquid coolant and the coolant is carried to the hot surface  
of the unit by wick action. The liquid coolant is ele-  
vated to a boiling temperature upon contact with ex-  
change surfaces, and the resulting vapor is permitted to  
escape to the atmosphere. The wick material retains  
the liquid coolant independently of the attitude of the  
electronic equipment and without the use of valves or  
other arrangements. Preferably a vented casing encloses  
the wick material and forced draft cooling of the wick  
material may be employed.

A second preferred application of the electronic cool-  
ing principles of this invention employs the placement of  
all of the parts of the electronic unit which must be  
cooled on top of a chassis and surrounding components  
with the wick material. A cover of the electronic chas-  
sis in this serves also as the container for the wick ma-  
terial. This arrangement protects the entire equipment  
from extreme temperatures generated outside of the  
electronic unit such as the high ambient temperatures  
encountered in high speed aircraft.

In a third preferred application of the electronic cool-  
ing principles of this invention, those parts of the elec-  
tronic unit which must be cooled are mounted on top of  
the chassis, and wick material is enclosed in a pressure  
tight container fitting down over the protruding electronic  
components in the manner of a glove being pulled over a  
finger. The pressure tight enclosure may have one or  
more projecting portions protruding down into the elec-  
tronic chassis to cool components below the chassis.  
There also may be provided a pressure regulating vent  
valve to regulate the pressure at which the liquid coolant  
boils, thus regulating its temperature.

Another application of the electronic cooling features  
of this invention utilizes wick material enclosing elec-  
trical units to be cooled and retained in a foraminous  
member. Cooling air may be circulated by suitable  
means over the foraminous member causing evaporation  
of the liquid and consequent cooling.

In order that all of the structural features for attain-  
ing the objects of this invention may be readily under-  
stood, detailed references are herein made to the drawings,  
wherein;

FIG. 1 is a perspective view, partly in section, of a de-  
vice forming one embodiment of the invention and hav-  
ing one of the electronic components surrounded by a  
wick to show the principle of this cooling method;

FIG. 2 is an enlarged, vertical sectional view of the  
device of FIG. 1 and taken along line 2-2 of FIG. 1;

FIG. 3 is a vertical sectional view of a device form-  
ing another embodiment of the invention;

FIG. 4 is an enlarged fragmentary vertical sectional  
view of a modification of the device of FIG. 1;

FIGS. 5, 6 and 7 are perspective and vertical views of

a device constituting a further embodiment of the invention; and

FIGS. 8 and 9 are vertical sectional views of devices forming alternate embodiments of the invention.

Referring in detail to the drawings, an electronic device 10 (FIGS. 1 and 2) has an outer shell 11 enclosing internal electrical and/or electronic components 12 of the device. For convenience of design, certain of the electronic components are enclosed within the shell 11 and a chassis 13, and other components 14 are placed on top of and protrude from the chassis. Those electronic components which are placed on top of the chassis are enclosed with cover 15 which has suitable openings 16 to allow air to circulate for ventilation and cooling. Electronic component 17, which requires cooling is enclosed with an annular band of wick material 18 which is held in place by annular pan or container 19, around the surface of the electronic component, which is sheathed exteriorly by a waterproof sheath. Container 19 has a snug fitting upturned lip 20 which makes a reasonably tight contact with the electronic component 17. The cover is held to the electronic chassis by known socket means.

The wick material 18 is advantageously suited for use in a system in which all of the liquid necessary for cooling can be contained within the amount of wick material placed in the container, for example, aircraft applications requiring but a few minutes of cooling. The maximum time is obtained by filling the spaces occupied by the wick material 18 with liquid coolant. This may be accomplished by a suitable bulb type filler 21, such as used for putting water in automobile batteries or with a suitable tube and funnel 22, which may be placed outside the electronic unit. As boiling or evaporation takes place to cool the electronic component, the amount of liquid diminishes, with the resulting vapor being released through the openings 16 in the cover. This action takes place because of contact of the wick material with the sheathed electronic component 17 on its outer surface. The contacting portion of the wick 18 then contains less moisture than the balance of the material, and the moisture that remains in the balance of the material is carried to the hot surface by the small capillary openings in the wick material to supply these surfaces with a constant amount of liquid to keep them wet. With this occurrence, the wick material will continue to draw the liquid to this hot surface by capillary attraction through its entire length, thereby keeping the hot surface supplied with liquid. At the same time, because the wick material 18 is porous, it permits the vapor to escape from all parts of this hot surface and travel upward to the openings in the cover 15. If the unit is turned on its side or inverted, the liquid will still be retained by the wick material and vapor will still travel to the openings 16 as the boiling action continues to take place.

If it is not convenient because of space or other limitations to provide sufficient wick material to contain a large enough quantity of liquid to cool for the time desired, then a separate reservoir 25 (FIG. 3) containing an additional supply of liquid 26 may be provided. This reservoir is connected in the same manner with tube 22A, as the filler funnel 22 is connected to the container holding the wick material. The reservoir is equipped with a suitable filler cap 27. The wick material 18 in the unit of FIG. 1 is placed only around the sides of the electronic component 17 to be cooled, leaving the top open and accessible for wires or terminal connections 28 to the component.

Referring to FIG. 3, an additional component 17A may also be cooled as well as component 17. This can be accomplished by enclosing component 17A with wick material 18A, which is held in place by container 19A, and connected with a piece of tubing 22B, which is an extension of the tubing 22A supplying wick 18. The liquid 26 in reservoir 23 now supplies the two electronic

components and may be made in any size to accommodate the required amount of coolant. Reservoir 25 is suitably located outside the cover 15 so that the level of liquid will not be higher than the levels of the wick material 18 and 18A to prevent overflow of the coolant during the filling operation of the reservoir. Since time is involved for the liquid to travel from the bottom of the container 19 and 19A in the wick material to the top (this time for liquid to travel through the wick is known as the wicking rate), the electronic unit may be turned on its side, tilted or turned upside down in a position in which the liquid level in the reservoir would be higher than the upper most portion of the wicks. There is a time, therefore, before the liquid will run out of the wick material because if its being saturated during which the unit which may be in an aircraft may be on its side or inverted because of a maneuver of the aircraft. If it is desired to extend this time because of the duration of the maneuver, than additional wick material may be placed in tubes 22A and 22B to slow up the rate at which liquid will travel to the wicks.

In the electronic unit shown in FIG. 4, sheathed electronic component 14 mounted on chassis 13 is cooled by evaporative wick unit 28 which comprises an inner flanged metal tube or socket cup 29 fittingly snugly over the sheath of component 14 and held securely thereon by friction. The tube 29 is suitably sealed by brazing of flanges of chamber 30 and wick material 31 of fiber glass or other suitable wicking substantially fills the container formed by the elements 29 and 30. The chamber 30 has top vent tube 33 closed by a perforated cap 34. The chamber also has top filling tube 35 closed by cap 36 for supplying liquid coolant to the chamber. Flanged chassis 13 is secured by screws to the cover to form a closed compartment and flanges of the chassis and cover 15 are secured together by screws 37.

The electronic unit 40 shown in FIGS. 5, 6 and 7 has cover 41 enclosing those components 12 which need not be cooled externally. Components 42, 42A and 42B are fixed to the top of the chassis. Components 45 such as transistors, and the like, whose temperature may be critical are mounted on a cold plate 46, and are cooled by thermal conduction to the plate 46 which has outer surface 43 in contact with wick material 48.

The cold plate 46 may be mounted on top of the chassis as 46 in a chamber 49 and may be an integral part of the chassis 51. The cold plate is shown as mounted in face to face contact with cover 50 so that the components mounted and connected make a component assembly with the cover, and the cover is embedded in the wick material, and these elements may be considered a component for cooling purposes.

The electronic unit 40 may consist of any combination of these described components or component assemblies.

The chassis is enclosed by bottom cover 52 and top cover 53. The wick material 48 is contained within the cover 53 and is supported on a suitable platform or pan 54. The mass of wick material 48 is proportionately large in volume and thus would have the potential to cool a large number of electronic components. Coolant liquid is poured into combined filling and vent opening 56 in the cover 53 until the desired quantity is contained in the wick material. The capillary openings in wick material 48 causes the coolant liquid to spread evenly throughout the mass of this wick material. When the electronic equipment is operated, the individual components to be cooled will dissipate their heat on the outer surface of the components or the plates 46 and 47. Inasmuch as the wick is in contact with these surfaces, the coolant liquid is boiled or evaporated from these surfaces. The porous wick enables the vapor to escape to the space 57 where it proceeds out through the opening 56 to the atmosphere.

FIG. 5 is a view showing details of pan 54. The pan

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54 supports the wick material 48 and has upper wall or flange 61 fitting snugly around sheath component 42 which is indicated by the dashed lines for clarity. The flange 61 of this platform fits snugly around component 42, and together with the outer lip or wall 63 forms a liquid tight trough in the immediate vicinity of component 42 located under or close to the opening 56 into which the coolant liquid is admitted. As the coolant liquid is poured into this opening, it will travel with an equal speed in all directions and will reach the opening 64 in drain tube 62 at the same time it would reach a point in the wick material equally distant from the drain opening. At this point, a mass of wick material of dimensions equal to the distance from tube opening 64 to the top will be saturated with this liquid. If at this instant, more liquid is poured into the wick and can travel further throughout its mass, then the excess will run out of tube 62 in the form of drops. If at this point, the entrance of the coolant liquid ceases, then the coolant will distribute to the balance of the mass of the wick material through its capillary openings until it is evenly distributed. At this point, the wick material immediately above the tube opening 64 will be only partially saturated and thus can hold more of the coolant. Now an additional quantity of coolant can be introduced into the mass of wicking until the excess again runs out of overflow tube 62. In this fashion, the entire mass of the wick material can be brought close to the point of saturation with the coolant liquid. The rest of support or pan 54 to the left of the component 42 as viewed in the drawings, thus does not need to be liquid tight since excess liquid will not leave the wick material unless it is saturated. Thus additional openings, such as 65 need not have the water tight lip formed on them if it is not desired to do so. In this fashion the mass of wick can be made to hold its maximum quantity of liquid without having any of it spill onto the top of the electronic chassis or outside of the cover. Because of this feature, both the cover 53 and the platform 54 need not be liquid tight except in the area previously described. The electronic unit 40 may be turned on any one of its sides or upside down while in this saturated condition and the boiling action against the hot surface 43 will continue to take place the vapors will escape to space 57 and out opening 56 regardless of attitude of the unit.

Referring now to FIG. 8, electronic unit 70 contains electronic components 71 enclosed by downwardly facing recesses 72 in partition 73. Components 74 not liberating sufficient heat to require external cooling are enclosed in cover 75. Components 71, 71A, and 71B are mounted on top of the chassis or partition to receive cooling. The components 71B may be cold plate assemblies. The partition 73 forms a pressure tight cover arranged with the suitable sleeve type openings to enclose the electronic components. The wall of the openings 72 fit over the components snugly so that they make contact or a space may be left between the sleeve and the component and filled with a finger contact type material and/or aluminum or other metal wool 76 to conduct the heat from the electronic component to the sleeve 72. The pressure tight cover 73 is secured to the chassis through suitable fasteners 77. Wick material 78 is suitably arranged in layers or other form inside container 79. Filling tube 80 selectively closed by pressure tight cap 81 is provided for filling this container with liquid coolant. Liquid coolant is poured through this opening until the wick material is saturated or the desired quantity of liquid has been admitted. The coolant will diffuse evenly throughout the mass of wick material, through the capillary openings in the wick. Vent tube 82 is filled with foraminous material 83 such as wicking, for example.

The partition 73 includes a hollow projection or finger 86 fitting snugly into sleeve 87 of coil 88 in the lower chamber. The wetted wick material 78 fills the finger 86 to very effectively cool the coil 88 by evaporation.

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When the electronic equipment is operated, the heat is dissipated from components 71 through their outer walls to the conducting material, 76 to the sleeves 72 of the container. The opposite surfaces of these sleeves are in contact with the liquid saturated wick and cause the liquid coolant to boil or evaporate. The vapors thus formed will find their way through the porous wick material to space 89 provided between the top of the wick and the pressure tight case 79. The vapors will then find their way to the outlet 82 and will be discharged overboard. If it is desired to regulate the boiling temperature of the coolant liquid a known pressure valve (not shown) may be added to the vent outlet. This would be the case where it is desired to boil water at say 14.7 p.s.i. absolute (sea level pressure) and then upon reaching an altitude where the ambient pressure is considerably lower maintain the same boiling pressure or temperature by virtue of having the pressure vent valve set to release the vapors at the desired pressure. The control valve may be set for any pressure and thus control the coolant liquid at any temperature level.

The vapor or steam, if water is used as a coolant, will form on the outer faces of the sleeves 72 between these faces and the wick material. Normally the vapor will rise along these faces until it must enter the wick material and then will find its way through the porous portions of the wick to space 89. The passage of this vapor through the wick material will cause a pressure drop in the vapor. In other words, the pressure at space 89 must be lower than the pressure at source of the vapors in order to have this vapor escape. This pressure may be added to that obtained by the control valve to regulate the boiling temperature. However, if this pressure drop is undesirable, then passages 90 or openings on top of the sleeves may be provided in wick material by foraminous sleeves 91 of screening or the like. The vapor thus is allowed to travel along the outer faces of sleeves 72 where the pressure drop is negligible into the opening 90, and thus to the space 89 on top of the wick with no appreciable pressure drop. This may be desirable where it is necessary to have the minimum boiling temperature (pressure).

It may be desirable to mount components 71C as a cold plate assembly on the underside of the partition 73. This may be done on a portion or wall of this surface. Thus it is possible to cool selectively either certain portions or all of the entire electronic equipment. This would be desirable in the event that outside ambient temperatures were such that the chassis components required cooling at these high ambient conditions where they might not at more normal ground level conditions.

While the unit 70 is described as an open system in which the vapors from the liquid coolant are vented to atmosphere, it will operate equally well as a closed system. A tube or pipe would be connected to the outlet 82 to carry the vapor to a compressor then a condenser to be liquified by a conventional refrigeration cycle. The coolant liquid would then enter the pressure tight case 73, through a control valve and piping to tube 80.

Referring to FIG. 9, electronic unit 95 has a chassis 96 and a bottom cover 97 enclosing electronic components 98 inside. One or more sheathed components 99 requiring cooling are placed on top of the chassis and enclosed by and in contact with sleeves 100 of wick material, which is contained in an open sleeve 101 or screen wire or equivalent and supported by flanged annular discs 102. Component 103 is shown mounted on cold plate 104 with a mass 105 of wicking retained by screen 106 and frame 107 on top of the chassis directly above the cold plate 104. These units are arranged to be enclosed by cover 111 which has opening 112 to admit forced draft cooling air. Coolant liquid may be placed in the wick material by any of the methods previously described, vent openings 113 being provided. Cooling air may be induced to flow over the wick material by natural draft or by induced draft circulation. The coolant liquid

evaporating into this air stream will lower the coolant temperature to that close to the wet bulb temperature of the entering coolant air. Thus it is possible to cool the electronic component below the boiling point of the coolant at that particular ambient pressure by evaporation of the coolant into the ambient air. This is important for such items as transistors many of which must be kept below 175 to 200° F. This evaporation in turn will lower the temperature of the air as well as cool components 99 and 103, and the cooler air may be then used to provide an additional amount of cooling for the balance of the components over which it will circulate.

The above units very effectively cool the electronic components, and are simple, light, rugged and inexpensive in construction.

It should be understood that the above described examples are merely illustrative of the principles of this invention, and that numerous modifications may be devised by those skilled in the art without departing from the scope of the invention.

What is claimed as new is:

1. A selectively cooled electrical component assembly comprising an enclosure assembly forming a plurality of chambers, means mounting one component in a first one of the chambers, heat conducting plate structure mounting a group of components in a second one of the chambers, means mounting components requiring little or no cooling in a third one of the chambers, the enclosure structure forming an additional chamber having a common wall heat transfer structure with the other chambers, and wetted wick material substantially filling the additional chamber and substantially surrounding the common wall portions of the additional chamber for selective evaporative cooling of the electrical components.

2. A selectively cooled electrical component assembly comprising an enclosure assembly forming a plurality of chambers, means mounting one component in a first one of the chambers, heat conducting plate structure

mounting a group of components in a second one of the chambers, means mounting components requiring little or no cooling in a third one of the chambers, the enclosure structure forming an additional chamber having a common wall heat transfer structure with the other chambers varying in area generally in accordance with the relative cooling required by the components in the respective chambers, and wetted wick material substantially filling the additional chamber and engaging the common wall structure for selective evaporative cooling of the electrical components.

3. The combination of claim 2 together with means forming unrestricted vapor conducting passages in the wick material extending from positions adjacent the upper ends of the first and second chambers to the upper surface of the wick material.

4. The combination of claim 3 together with metal wool packed between the one component and the adjacent portion of the common wall structure for rapid conduction of heat from the one component.

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