

April 29, 1952

M. B. LEMESHKA

2,595,150

COOLING UNIT

Filed March 31, 1949

Fig. 1

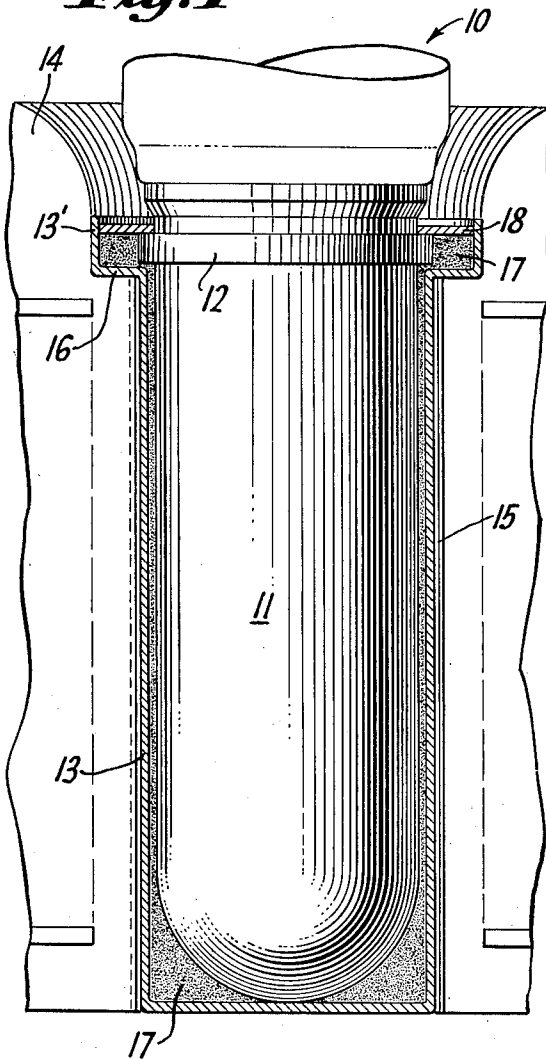


Fig. 2

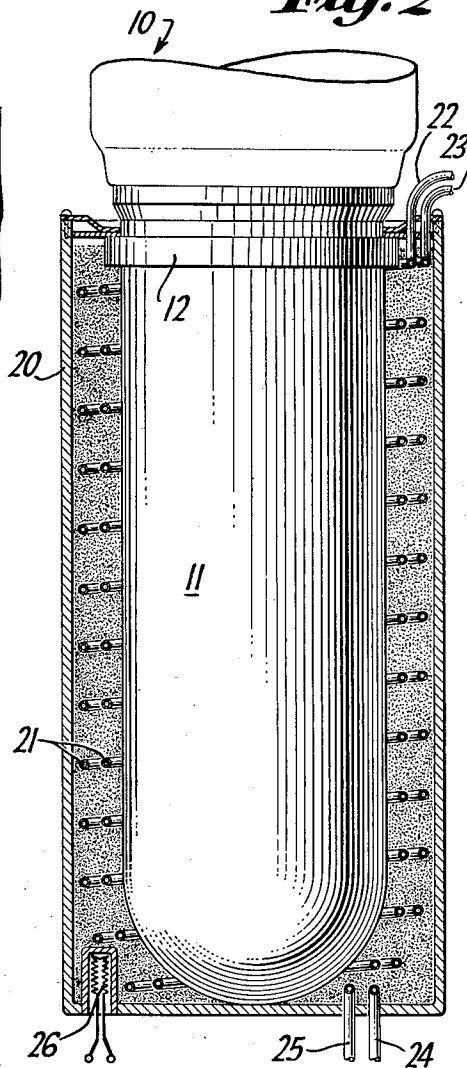
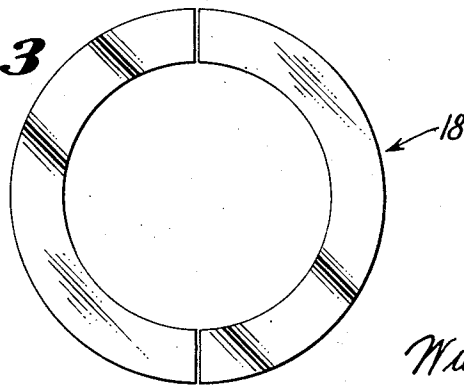


Fig. 3



INVENTOR
MILTON B. LEMESHKA
BY
William A. Zalesak
ATTORNEY

UNITED STATES PATENT OFFICE

2,595,150

COOLING UNIT

Milton B. Lemeshka, Lancaster, Pa., assignor to
Radio Corporation of America, a corporation
of Delaware

Application March 31, 1949, Serial No. 84,631

10 Claims. (Cl. 313-21)

1

This invention relates to cooling units through which a heat exchange medium is passed and more particularly to such units which are subject to temperature cycling in normal use.

For the purpose of illustrating my invention it will be described in connection with an electron discharge device having an external surface or electrode to be cooled, although it is to be understood that it is not limited to that particular construction. In accordance with the common practices embodied in the design of external cooling units either a gas or liquid is utilized as the heat exchange medium in conjunction with a receptacle which is designed to receive the portion to be cooled therein. The problems attending the cooling of such devices have become progressively more difficult as the power output and frequency has been increased. In the case of a liquid medium which is passed through a conduit such as a coiled pipe or the like, the problem of effecting a good thermal bond between the conduit and the cooled surface is present. In the case of forced air cooling an array of cooling fins is generally connected to a core which may serve as a receptacle for the portion of the device to be cooled. Such a unit is shown in my co-pending patent application Serial Number 68,335 filed December 30, 1948 and in the co-pending application of Anthony G. Nekut, Serial Number 68,173 filed December 30, 1948, both assigned to the same assignee as the present application.

Such forced air cooling units have been generally made of copper because of its good thermal characteristics and because of the problem of effecting a good thermal bond between the cooling unit and the cooled device which in practice has an external copper electrode. However, as the size and hence the weight of such units has increased the cost thereof as well as the substantial weight has become a serious disadvantage. It has been proposed and attempts have been made to form the cooling unit of a lighter metal such as aluminum. Though such units may be readily fabricated from aluminum, the problem of effecting a bond between the aluminum core, receptacle, or conduit and the copper electrode of the electron discharge device which would survive temperature cycling has up to now proven unsurmountable. At 100° C. the coefficient of thermal expansion of aluminum is 235×10^{-6} while for copper it is 166×10^{-6} . Thus, though a cooler of conventional design may be readily fabricated from aluminum and soldered to a copper electrode, once the solder has solidified and remains solid the temperature of the electrode and cooler

2

cannot be varied without setting up mechanical stresses in the region of the solder joint, because of the difference in expansion between the aluminum and the copper. The magnitude of the stresses developed in the normal operating temperature cycle exceeds the mechanical strength of all known soft (melting point 300°-250° C.) solders. Deterioration of the thermal bond between the cooler core and the electrode manifests itself by an increasing temperature drop between the two and a rise in electrode temperature beyond permissible limits.

Thus, a principle object of my invention is to provide a cooler considerably reduced in cost and of improved efficiency.

Another object is to provide a mechanical bond between the cooler and the device or part thereof to be cooled which effectively connects the two under static temperature conditions normally encountered and yet which provides a high performance thermal bond during operation of the cooler and the device which will overcome any tendency of stress to develop between the cooler and the device.

A still further object is to provide an electron discharge device with a liquid or forced air cooler having a thermal coefficient of expansion substantially different from the device which is normally mechanically connected thereto and which when the device is put into operation has a good thermal bond therewith in spite of any amount of temperature cycling.

Yet another object is the provision of an improved thermal bond between a conduit for a liquid coolant and the part of an electron discharge device to be cooled.

Still other objects will appear as the nature of my invention is more fully understood from the following description taken in conjunction with the accompanying drawings wherein like parts are designated by identical numerals in the several views.

In carrying out my invention, I utilize a fusible alloy to join the cooler to the part of the device to be cooled such as the anode of an electron discharge device, the alloy having such a melting point that it is liquid at the operating temperature of the cooler and electron discharge device. A heating element may be utilized to provide means for heating the fusible alloy, particularly where relatively large quantities of the alloy are used, to facilitate removal of the device from the cooler when the device is not in operation.

The novel features which I believe to be characteristic of my invention are set forth with par-

ticularity in the appended claims, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawing in which:

Figure 1 is a longitudinal sectional view, partially in elevation of an electron discharge device and a forced air cooler therefore constructed in accordance with my invention and showing only those parts necessary to an understanding of my invention;

Figure 2 is a view similar to Figure 1 of an electron discharge device and a liquid type cooler; and

Figure 3 is a plan view of the cover for the central portion of the cooler shown in Figure 1.

In view of the weight or cost of a cooler for an electron discharge device, the use of a lighter metal such as aluminum for the fabrication of the cooler rather than copper as was the usual practice, has great advantages since the weight of aluminum is approximately 30% that of copper while the thermal conductivity thereof is substantially 55% of copper. It is evident that an aluminum cooler will weight only approximately 54% as much as its equivalent made of copper and with the cost of these metals being substantially the same at the present time an equivalent saving in cost is also made.

For the purpose of illustrating my invention, I have shown part of an electron discharge device 10 having, as a part thereof to be cooled, an external copper anode 11 with an annular flange 12. The cooler which is fabricated entirely of aluminum has a receptacle-like portion or core 13 to which may be assembled fins 14. The particular construction and arrangement of fins 14 about receptacle-like portion or core 13 forms no part of my present invention and may be carried out in any desired manner. As illustrated in Figure 1, such a forced air type cooler may be constructed as is fully disclosed in the co-pending applications referred to hereinabove, Lemeshka, Serial No. 68,335 or Nekut, Serial No. 68,173, with a plurality of fins 14, arranged in a radial array, having complementary flanges 15 which nest with the flanges of adjacent fins. Flanges 15 are joined to one another and to the core by means of soldering, brazing or the like.

My invention is not limited to forced air coolers as the heat exchange means but is also applicable to liquid coolers utilizing a liquid heat exchange medium such as water as will presently appear. In carrying out my invention with respect to such forced air coolers, I provide a receptacle-like core 13 which is closed at one end and open at the other. The open end of the core and a portion 13' thereof for some distance toward the closed end has an increased diameter formed by a transverse shoulder 16 and which acts as a well. The outside diameter of the electrode 11 is sufficiently less than the inside diameter of the core as to permit free flow of solder 17 therebetween and so that there will be no physical contact between the two. Furthermore, the dimensions are such that the electrode will rest on the bottom or closed end of the core with flange 12 above and not in contact with shoulder 16.

The solder or alloy which serves as the thermal coupling or heat transfer medium between the part to be cooled and the cooler or heat exchange means must have a melting or fusion point such that it is in the liquid state well below the operating temperature of the cooled part

and the cooler and should not alloy in the liquid state with either the cooled part or the cooler. Furthermore, such a heat transfer medium or solder must not oxidize seriously and must have sufficient thermal conductivity.

In connection with the illustrated electron discharge device, the accepted standard is a core temperature of 180° C. The alloy which I prefer to use as the solder between an aluminum cooler and copper electrode is the lead-bismuth eutectic (commercially available as "Cerrobased"; Cerro de Pasco Corp., New York, N. Y.) which melts at 124° C. Such an alloy is solid at ordinary ambient temperatures encountered while the device is not in operation and permits handling of the electron discharge device and its cooler as a unit. During operation the temperature of the core rises to approximately 180° C. while the solder alloy which acts as the heat transfer medium between the receptacle-like core and the electrode completely liquefies well below this temperature in view of its relatively low fusing temperature. Thus, in spite of the difference in the relative expansion and contraction of the aluminum core and copper electrode and in view of the liquid state of the heat transfer medium between the two, no mechanical stresses arise between the two above 124° C. and hence deformation of the copper electrode is avoided.

I have found that in practice as the solder alloy liquefies or fuses a certain amount thereof is squirted upwards probably as a result of the central portion of the alloy melting first thus setting up a slight pressure under the top crust of alloy which causes a small quantity to be squirted through the first opening which appears in the top crust as the latter starts to melt. To avoid gradual depletion and loss of the alloy in the excess solder well, I provide a cover 18 in the form of a split ring as shown most clearly in Figure 3 which serves to close the excess solder well at the open end of core 13. The well formed by portion 13' of core 13 holds an excess of solder over that required in the space between the core and the electrode to insure that the same is always completely filled and at the same time acts as a receiver for any solder alloy which may tend to overflow from said space as a result of expansion of the liquid alloy.

As pointed out hereinabove the aluminum core is free to contract as it cools from operating temperature down to approximately 124° C. without imposing any stresses upon the copper electrode. However, as the aluminum core continues to cool down to room temperature after solidification of the solder alloy it still tends to contract somewhat faster than the copper electrode. After only a single temperature cycle the resulting radial deformation of the copper electrode is insignificant but since such deformations are cumulative with each subsequent temperature cycle, they may not be ignored if tube failure from this cause is to be avoided. For example, I have found in the case of tube type 9C22 having a .600 inch aluminum core wall thickness, the radial deformation of the 4.500 inch diameter anode after 655 temperature cycles (equivalent to approximately 10,000 hours life in normal service) was .017 inch inward in diameter by test. I have shown that reducing the thickness of the aluminum core wall to substantially less than the thickness of the anode or to .250 inch will eliminate even this relatively small deformation.

Where it is desired to have a liquid thermal bond between the aluminum cooler and the copper electrode at a temperature lower than that afforded by the lead-bismuth eutectic, I utilize other alloys. One such alloy is essentially approximately 52% bismuth, 40% lead and 8% cadmium, by weight, having a melting point of approximately 91° C. Another such alloy contains essentially approximately 52.5% bismuth, 32% lead and 15.5% tin, also by weight, and having a melting point of approximately 96° C.

In Figure 2 I have shown the heat exchange means as one adapted for use with a liquid coolant such as water. Electrode 11 seats in receptacle-like portion 20 which may contain one or more conduits as for example tubing 21 wound in a double helix and connected to inlet 22 and outlet 23. An auxiliary inlet 24 and outlet 25 may be provided in convenient locations as indicated. A resistance element 26 may be conveniently utilized to heat and liquify the fusible alloy to facilitate removal of the device when not in operation from the cooler. In operation the alloy is in the liquid state and is in intimate contact with the coil and the electrode, affording an efficient thermal path therebetween, and resulting in considerably more uniform temperature distribution over the electrode than is normally the case when a coil is utilized which is merely wound around the electrode or connected thereto by solder which is solid during operation. Furthermore, in the case of the great power dissipation from an anode electrode where intense cooling is necessary it is no longer essential that the liquid wash over the electrode itself and subject the same to a relatively large pressure as would be the case in a closed system. By using a fusible alloy the efficiency of the coil is greatly improved by the fact that it affords an interface area between the coolant and the electrode surface through the fusible alloy which is far greater than that which is the present limit of such systems where the water is in contact with the electrode surface.

If additional mechanical connection between the cooler and the electron discharge device is desired or if it is desired that they be mechanically connected during operation a few bolts may be readily used to clamp the device to the cooler as far example in the region of flange 12.

It is apparent from the foregoing that when a fusible alloy is utilized as the heat transfer medium between an aluminum cooler and a copper electrode deterioration of the thermal bond does not occur as would be the case when the usual solders are utilized where the difference in expansion tends on the one hand to cause separation of the solder from the aluminum and copper or both and on the other hand to cause permanent deformation of the copper electrode as a result of the compressive strains imposed during contraction of the aluminum. This as well as the improved liquid type cooler makes possible substantially improved high efficiency coolers with a substantial reduction in weight and cost. Thus, while I have set forth the foregoing embodiments of my invention and described it in detail with respect thereto, I do not wish to be limited to the exact construction set forth but desire to claim all modifications thereof that come within the scope of the appended claims.

What I claim is:

1. The combination with an electron discharge device having a part to be cooled, of a cooler hav-

ing a coefficient of expansion substantially different from that of the part to be cooled and including a receptacle-like portion, said part being seated in said portion, and a normally solid heat transfer medium forming a mechanical bond between said cooling unit and said device when solid and having a melting point below the normal operating temperature of said cooler for improved cooling of the part to be cooled.

2. The combination with an electron discharge device having a part to be cooled, of a cooling unit including a receptacle-like portion, said part being seated in said portion, a normally solid heat transfer medium connecting said part to said receptacle-like portion, and means in said receptacle-like portion for liquifying said heat transfer medium.

3. The combination with an electron discharge device having a metallic electrode including walls to be cooled, of a cooler having a coefficient of expansion substantially different from that of the electrode to be cooled and including a receptacle-like portion, the walls of said portion being substantially thinner than the walls of said electrode, said electrode being seated in said portion, and a normally solid readily fusible heat transfer medium in contact with and between said electrode and said portion, said heat transfer medium having a fusion point below the normal operating temperature, and above the non-operating temperature of said electrode and said portion, whereby said heat transfer medium fixes said cooler with respect to said electrode at said non-operating temperatures, and improves heat transfer from said walls of said electrode during said operating temperature.

4. In an electron discharge device, an electrode having life cycles of successive predetermined relatively low and predetermined relatively high temperatures, a heat exchanger surrounding and spaced from said electrode, and a heat transfer medium between said electrode and said heat exchanger, said heat transfer medium being fluid at said predetermined relatively high temperatures and solid at said predetermined relatively low temperatures, whereby said heat transfer medium mechanically fixes said heat exchanger with respect to said electrode during said relatively low temperatures and is characterized by improved heat transfer properties during said relatively high temperatures.

5. In combination, a device having a part to be heated to a predetermined temperature and normally at a lower temperature than said predetermined temperature, a heat exchanger around and spaced from a portion of said part, and a heat transfer medium between said heat exchanger and said portion comprising a material having a melting point higher than said lower temperature for normally mechanically connecting said heat exchanger and said part to be heated, and lower than said predetermined temperature for fusing at said predetermined temperature to improve the thermal bond between said part and said heat exchanger, and for relieving strains due to different mechanical responses of said part and said heat exchanger to said predetermined temperature.

6. In combination, an electron discharge device having a copper electrode to be cooled when operating at a predetermined temperature, an aluminum cooler comprising a receptacle for receiving a portion of said electrode in spaced relation with respect to the inner walls of said re-

7

ceptacle, and a heat transfer medium between said portion of said electrode and said inner walls, said medium comprising a material having a melting point below said predetermined temperature, whereby said material becomes fluid at said predetermined temperature for improved contact with said electrode and said cooler and improved heat transfer from said electrode to said cooler, said material having a melting point above the normal temperature of said electrode for mechanically fixing said electrode with respect to said cooler during non-operating periods.

7. A heat transfer medium for use between a part subjected to cycles of temperature variations from below 124° C. to above 124° C., and a heat exchanger, said medium comprising an alloy of bismuth and lead in eutectic forming proportions, said alloy having a melting point of approximately 124° C., whereby said alloy is solid during relatively low temperature portions of said cycles for fixing said part to said heat exchanger, and fluid during relatively high temperature portions of said cycles for improved heat transfer from said part to said heat exchanger.

8. A heat transfer medium for fixing a part to be heated to a heat exchanger during dormant periods when said part is unheated and for improving heat transfer for said part to said heat exchanger when said part is heated, said medium comprising an alloy containing essentially of about 32 per cent bismuth, about 40 per cent lead, and about 8 per cent cadmium.

9. A heat transfer medium having a melting point below a predetermined temperature of operation of a part to be cooled and engaged by said medium comprising an alloy consisting essentially of about 52.5 per cent bismuth, about

8

32 per cent lead, and about 15.5 per cent tin, whereby said medium is fluid at said predetermined operating temperature for improved heat transfer from said part.

10. In combination, a device having a part to be heated to a predetermined temperature above 124° C. and normally at a lower temperature than said predetermined temperature. A heat exchanger around and spaced from a portion of said part, and a heat transfer medium between said heat exchanger and said portion, said heat transfer medium comprising an alloy of bismuth and lead in eutectic forming proportions, said alloy having a melting point of approximately 124° C., whereby said alloy fuses at said predetermined temperature to improve the thermal bond and relieve strains between said part and said heat exchanger, and is solid at said lower temperature for mechanically connecting said heat exchanger and said part to be heated.

MILTON B. LEMESHKA.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,318,832	Birdsall	Oct. 14, 1919
2,006,731	Chesnut	July 2, 1935
2,186,563	Suydam	Jan. 2, 1940
2,235,669	Conklin	Mar. 18, 1941
2,324,533	Pearson	July 20, 1943
2,440,245	Chevigny	Apr. 27, 1948

FOREIGN PATENTS

Number	Country	Date
349,719	Great Britain	June 4, 1931
473,792	Great Britain	Oct. 20, 1937