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DRAWINGS ATTACHED.



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COMPLETE SPECIFICATION.

Device for the Evaporative Cooling of Hot Bodies.

We, COMPAGNIE FRANCAISE THOMSON-HOUSTON, a French Body Corporate of 173 Boulevard Haussmann, Paris VIII, France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to the evaporative cooling of hot bodies in which a large amount of heat is given off which must be evacuated with a high thermal flux density without the heated body exceeding the maximum temperature prescribed for its good preservation.

The anode of a powerful electronic tube represents a particularly important example of a hot body presenting a problem of this nature, and the following description will refer more especially to the cooling of such tubes, given as a non-limiting example.

The invention specifically relates to the case in which the cooling is effected essentially by the vaporisation of a liquid in which the hot body is either wholly or partially immersed.

The irreversible phenomenon which causes local superheating or "calefaction" as soon as the temperature of the hot surface exceeds by about 25° C. the boiling temperature of the liquid had made it necessary to abandon all previous attempts to cool electronic tubes by vaporisation of water. It has been mastered and forced back to much higher powers by the use of the devices described in Patent No. 706,209.

A profound study of the functioning of the electronic tubes known as "Vapotrons" (Registered Trade Mark) manufactured in accordance with these principles by the applicant Company has shown that the device owes its surprising effectiveness to the

continuity of the temperature gradient set up along the individually massive protuberances or appendages, between their hot base and the end kept relatively cold by the liquid in which it is immersed, beyond the zone in which the intense heat exchange produces boiling.

The present invention consists in a device for the evaporative cooling of hot bodies with high thermal flux, especially for anodes of electronic tubes, in which the hot body is in contact with a radiator comprising radial appendages in the form of massive ribs or short thick protuberances, cooled by partial evaporation of the liquid in which the radiator is immersed, characterised by the fact that the end portions of the radial appendages are provided with additional heat exchange structures in intimate heat exchange contact with said end portions and arranged in such a manner that these end portions have with the liquid a larger effective contact area per unit of length, taken in the radial direction, than have the portions of the radial appendages situated between their base and said heat exchange structures.

The invention will now be described with reference to the accompanying drawings in which Figure 1 illustrates the principle of the invention and Figures 2 to 15 show various embodiments.

Figure 1 shows, in cross-section, an example of an element in accordance with the prior state of the art, in the case of an electronic tube of the "Vapotron" (Registered Trade Mark) type. The anode 1 is thickened, it is provided with individually massive appendages 2 the dimensions of which are large in relation to those of the steam bubbles, separated by spaces 3 which preferably constitute vertical chimneys in

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which the emulsion of water and steam rapidly rises. Boiling occurs on the lateral surface of the appendages in the region of their base 4 and extends over the sides 5 when the power to be dissipated increases. If the appendages are sufficiently massive, the migration of this zone of exchange by boiling as a function of the power is stable and reversible. The anode body 1 is preserved from overheating by good thermal conductivity with the appendages, the temperature of which is limited by the boiling at their contact.

Experience has shown that this stable functioning depends essentially on the presence of a "cold" metal mass at the end 6 of the appendages, and that the upper limit of power susceptible of dissipation is reached when said terminal region participates to an appreciable extent in the heat exchange by boiling.

The present invention consists in an improvement to the devices over the prior art as described hereinabove.

The operation of these devices is improved according to the present invention, and the maximum power of use is substantially increased, by intensifying the local cooling of the end 6 of the appendages so as artificially to decrease the temperature of this "cold point" necessary to stabilisation of the temperature gradient along the appendages 2.

The various embodiments of the principle of the invention comprise the addition to the end 6 of each of the massive appendages 2, and in good thermal contact therewith, of an additional heat exchange element 8 provided with means by which the temperature can be locally decreased, in order to constitute a definite cold point.

It must be noted that this condition will readily be attained, by local evacuation of a very small amount of heat, because of the thermal resistance of the element 2 which connects it to the hot point 1, but this stabilisation of the "cold point" will entail the possibility of a substantial increase in the heat exchange by boiling on the sides 5 of the appendages and at the base 4 thereof, the temperature of which may attain and even exceed appreciably the critical temperature of 125° C. without any risk of "calefaction".

The following figures show by way of non-limitative example various forms of construction according to the invention.

Figures 2 to 9 show embodiments wherein additional heat exchange structures of Figure 1 are formed by extensions of the appendages 2 having an increased contact with the liquid in which they are immersed beyond the zone in contact with the vapour. According to Figure 2, the increase of the surface of contact of the extension 8 may be

achieved by mechanical machining 9 which multiplies two or three times the useful area for heat exchange with the liquid, or any other equivalent form of local indentation of the surface.

According to Figure 3, the extension 8 can be cut into crenellations and, for example, the crenellations may be bent in alternate directions. There are thus obtained highly effective means for producing turbulence in the liquid current circulating in this region through a spontaneous thermo-siphon movement or one which is accelerated by an external cause.

Figure 4 gives an example of the combination of the two foregoing embodiments. It is possible for the sides of the extensions 8a, 8b to have knurling 9.

It will be noted that the examples given in Figures 2, 3 and 4 apply to any of the forms of the massive appendages 2 in accordance with the prior art.

A very interesting construction, according to Figures 3 or 4, relates to rectilinear and vertical elements 2 constituting massive ribs which can be obtained by vacuum casting of a single block with the body 1, the extensions 8 of which are cut out and curved in alternate directions, giving the whole the appearance of teeth in staggered arrangement, while the chimneys 3 are rectilinear in the zone in which heat exchange takes place by vaporisation. This arrangement has the advantage of not disturbing by unnecessary turbulence the working in the zone 4 in which boiling, of itself, ensures the most effective heat transfer, while the extensions 8 benefit from the staggered arrangement which gives rise to vigorous turbulence and hence to the maximum efficiency of heat exchange in that region where the liquid is subject to rapid displacement.

All the variants which may easily be conceived of said massive extension 8, arranged to effect the optimum heat transfer without local boiling, may profit from the use of a coaxial deflecting cylinder 10 intended to canalise the thermo-siphon movement by separating the rising from the falling jets. This deflector 10 can be carried by the extensions 8 and, for example, be formed integrally with their ends and, if desired, be in intimate contact with them, as shown in Figure 4.

It may likewise be spaced from the extensions 8 by the distance found to be best, as a rule several millimetres, as shown in Figure 3, and in that case it may form part of the evaporator associated with the structure, not shown in the drawing.

Figure 5 shows a different construction according to the invention, in which the extensions 8 of the massive vertical ribs 2 are slit longitudinally and symmetrically bent back, at 8a and 8b.



75 means



18

In Figure 6 the extensions 8 are members 8c soldered on to the end of the vertical ribs 2, the surface of said terminal members being, if desired, increased by knurling 9.

Particularly in these two latter embodiments of the invention, it is preferable to leave between the extensions 8 an interval 11 of a width sufficient to ensure that the vertical channels 3 shall not be laterally closed.

Systematic experiments have in fact shown that channels closed laterally do not function so calmly, at high rates of operation, with periodic delivery of vapour bubbles towards the base and notable decrease of the maximum power that the structure can dissipate on overload as compared with the performance of structures whose channels communicate laterally with the liquid. It is therefore preferable to avoid this too narrow canalisation of the emulsion of liquid and vapour, by forming continuous apertures 11 or separate apertures 12, 13.

Figure 7 shows, for example, a structure in which all the extensions 8 are formed by a cylindrical metal sleeve soldered in contact with the ends 6 of the radial appendages 2 having the form of massive parallel ribs.

The deleterious continuity of lateral closure of the vertical channels 3 is, according to the invention, interrupted by circular grooves 12.

Figure 8 shows an embodiment of this latter form wherein the thickened anode is a casting and comprises, as is known, parallel channels 3 obtained by casting cores. Lateral openings 13 are shown in the form of cylindrical holes, but it would just as well be possible to make parallel grooves, such as 12, or a helicoidal groove having a pitch equal to the interval of said grooves 12. Possible knurling or milling 9 of the external surface 8 has also been indicated.

Finally, Figure 9 represents any structure in accordance with the prior art on which the assembly of extensions 8 is constituted by a perforated sheet-metal plate 8, of a metal which is a good conductor of heat, soldered to the ends 6 of the radial appendages 2. This form of construction comprising a large number of holes 13 is applicable for all the known forms of these ribs or protuberances and especially for the most complex forms comprising pyramidal protuberances in a staggered arrangement.

All the various embodiments according to the invention designed on the principle of Figures 5 to 9 are equally able to profit from the addition of a coaxial deflector 10 such as that shown by way of example in Figures 2, 3 and 4. This deflector, the optimum position of which is situated at 5 to 10 millimetres from the radial ends of the extensions 8, will be advantageously carried by the boiler in which the electronic tube is

immersed rather than by the anode structure.

The embodiments of the invention which have been described above are highly effective and will be found to fulfil most needs which could not be met satisfactorily by the most improved techniques of the prior art.

There are however some exceptional instances which demand yet higher performances or in which lack of space does not allow the extensions 8 to be given the necessary development and clearance. It may then be found that the large amount of vapour 7 formed in the chimneys 3 may have an adverse effect on the contact of the liquid with the extensions 8, at very high rates of dissipation.

In such a case, it is advantageous to give practical effect to the principle of the invention by an application of means directed towards the same essential object, namely to ensure the stability of the temperature at the ends 4 of the massive appendages 2.

The following figures represent various forms of construction which avoid interference between the two heat exchange processes, of which the coexistence assures the surprising functioning and performance of "Vapotrons" (Registered Trade Mark). These two heat exchange processes are vaporisation at the base 4 of the appendages and convection without appreciable vaporisation at the "cold" ends 6.

This latter improvement consists in ensuring the stability of the "cold point" at the end 6 of the protuberances by means of heat exchange structures in the form of closed cooling channels 14, arranged in the mass of the end portions 6 of appendages 2 or in contact with them, which results in increasing the effective contact area of these end portions with the liquid. In these channels 14 is set up a thermo-siphon circulating movement independent of the movement of the emulsion rich in vapour escaping from the chimneys 3.

The following figures give some non-limiting examples of embodiments of said improvement.

In Figure 10 is shown, in cross-section, a part of an anode radiator 1 having massive vertical ribs 2, modified by being drilled in the immediate vicinity of their ends 6 with a channel 14 of circular section.

It will be seen that if a structure of this kind is immersed in a liquid which is to cool the same, two independent thermo-siphon movements will be set up, one in the vertical chimneys 3, with intensive vaporisation at the base 4 and on the flanks 5 of the ribs 2, the other in the channels 14 which will be decidedly freer from vapour bubbles, the power dissipated in channels 14 being much weaker than that which produces boiling in the chimneys 3.

Experience has moreover shown that the useful heat exchange in said channel 14 occurs only over the half of its inner surface towards the anode, while the other half merely acts as a wall which may be thin of even non-conducting.

Figure 11 shows a form of construction in which the channel 14 is constituted by a metal tube 17 welded into a groove 15 at the end 6 of the ribs 2. Such an arrangement is compatible with protuberances resembling a row of teeth, in accordance with embodiments illustrated in Figures 3a and 3b of Patent No. 706,209 or similar embodiments.

Figures 12 and 13 show embodiments in which the grooves 15 in the vertical ribs 2 are simply closed by an applied metal band 18.

All these devices are compatible with the use of a coaxial cylinder 10 intended to guide the thermo-siphon movement in the chimney 3.

The channels 14 do not require to be closed laterally in fluid-tight manner and it is perfectly possible, as shown in Figure 14 for the auxiliary grooves 15 to be closed collectively by approximate contact with the coaxial cylinder 10 where the dimensions of the main chimneys 3 are such that the presence of the cylinder 10 in this position is compatible with their functioning properly.

Finally, Figure 15 shows a particular case of an "internal anode", in which the ends 6 of the vertical ribs 2 separated by chimneys 3 are in contact with channels 14.

Naturally, the devices in accordance with Figures 10 to 15 can be combined with the other features already described, and particularly with the arrangements for increasing the surface in contact with the liquid, such as for example a knurling 9 of the ends 6, or their extensions 8.

WHAT WE CLAIM IS:—

1. A device for the evaporative cooling of hot bodies with high thermal flux, especially for anodes of electronic tubes, in which the hot body of a generally circular cross-section is in contact with a radiator comprising radial appendages in the form of massive ribs or short thick protuberances, cooled by partial evaporation of the liquid in which the radiator is immersed, characterised by the fact that the end portions of the radial appendages are provided with additional heat exchange structures in intimate heat exchange contact with said end portions and arranged in such a manner that these end portions have with the liquid a larger effective contact area per unit of length, taken in the radial direction, than have the portions of the radial appendages situated between their base and said heat exchange structures.

2. A device as claimed in Claim 1, in which the end portions of the radial appendages are provided with corrugations.

3. A device as claimed in Claim 1, in which the end portions of the radial appendages are cut out as crenellations and bent alternatively in two directions.

4. A device as claimed in Claim 1, 2 or 3, including a metal deflector in good thermal contact with the ends of the radial appendages.

5. A device as claimed in Claim 1, in which the end portions of the massive ribs are slit longitudinally and bent back on both sides to leave a free space, thus avoiding the lateral closure of the channels existing between the ribs or protuberances.

6. A device as claimed in Claim 1, in which the additional heat exchange structures are constituted by metal members having a good thermal conductivity soldered to the ends of the ribs or protuberances.

7. A device as claimed in Claim 1, in which a common additional heat exchange structure is constituted by a cylinder having a good thermal conductivity soldered to the ends of the ribs or protuberances, said cylinder being interrupted by discontinuities providing a sufficient number of lateral communication inlets between the channels and the liquid in which the structure is immersed.

8. A device as claimed in Claim 1, in which a single-block radiator obtained by casting comprises parallel channels which are laterally closed by a thin layer of metal, the continuity of which is broken by a number of holes providing lateral communication between the channels and the liquid in which the structure is immersed.

9. A device as claimed in Claim 8, the external surface of which is increased by knurling or milling.

10. A device as claimed in Claim 1, in which a common additional heat exchange structure attached to the ribs or protuberances is constituted by a sheet of perforated metal having a good thermal conductivity soldered on to their ends.

11. A device as claimed in Claim 1, 2, 3 or any one of Claims 5 to 9, in combination with a coaxial deflector situated at a short distance from the external surface of the structure.

12. A device as claimed in Claim 1, in which the extremity of each of the ribs or protuberances is solid with a vertical metal conduit forming an auxiliary channel in which the liquid circulates by thermo-siphon effect without much vaporisation, irrespective of the tumultuous vaporisation which fills with vapour the main channels existing between the massive ribs or protuberances.

13. A device as claimed in Claim 12 in which the auxiliary channels are only

Experience has moreover shown that the useful heat exchange in said channel 14 occurs only over the half of its inner surface towards the anode, while the other half merely acts as a wall which may be thin of even non-conducting.

Figure 11 shows a form of construction in which the channel 14 is constituted by a metal tube 17 welded into a groove 15 at the end 6 of the ribs 2. Such an arrangement is compatible with protuberances resembling a row of teeth, in accordance with embodiments illustrated in Figures 3a and 3b of Patent No. 706,209 or similar embodiments. Figures 12 and 13 show embodiments in which the grooves 15 in the vertical ribs 2 are simply closed by an applied metal band 18.

All these devices are compatible with the use of a coaxial cylinder 10 intended to guide the thermo-siphon movement in the chimney 3.

The channels 14 do not require to be closed laterally in fluid-tight manner and it is perfectly possible, as shown in Figure 14 for the auxiliary grooves 15 to be closed collectively by approximate contact with the coaxial cylinder 10 where the dimensions of the main chimneys 3 are such that the presence of the cylinder 10 in this position is compatible with their functioning properly.

Finally, Figure 15 shows a particular case of an "internal anode", in which the ends 6 of the vertical ribs 2 separated by chimneys 3 are in contact with channels 14.

Naturally, the devices in accordance with Figures 10 to 15 can be combined with the other features already described, and particularly with the arrangements for increasing the surface in contact with the liquid, such as for example a knurling 9 of the ends 6, or their extensions 8.

WHAT WE CLAIM IS:—

1. A device for the evaporative cooling of hot bodies with high thermal flux, especially for anodes of electronic tubes, in which the hot body of a generally circular cross-section is in contact with a radiator comprising radial appendages in the form of massive ribs or short thick protuberances, cooled by partial evaporation of the liquid in which the radiator is immersed, characterised by the fact that the end portions of the radial appendages are provided with additional heat exchange structures in intimate heat exchange contact with said end portions and arranged in such a manner that these end portions have with the liquid a larger effective contact area per unit of length, taken in the radial direction, than have the portions of the radial appendages situated between their base and said heat exchange structures.

2. A device as claimed in Claim 1, in which the end portions of the radial appendages are provided with corrugations.

3. A device as claimed in Claim 1, in which the end portions of the radial appendages are cut out as crenellations and bent alternatively in two directions.

4. A device as claimed in Claim 1, 2 or 3, including a metal deflector in good thermal contact with the ends of the radial appendages.

5. A device as claimed in Claim 1, in which the end portions of the massive ribs are slit longitudinally and bent back on both sides to leave a free space, thus avoiding the lateral closure of the channels existing between the ribs or protuberances.

6. A device as claimed in Claim 1, in which the additional heat exchange structures are constituted by metal members having a good thermal conductivity soldered to the ends of the ribs or protuberances.

7. A device as claimed in Claim 1, in which a common additional heat exchange structure is constituted by a cylinder having a good thermal conductivity soldered to the ends of the ribs or protuberances, said cylinder being interrupted by discontinuities providing a sufficient number of lateral communication inlets between the channels and the liquid in which the structure is immersed.

8. A device as claimed in Claim 1, in which a single-block radiator obtained by casting comprises parallel channels which are laterally closed by a thin layer of metal, the continuity of which is broken by a number of holes providing lateral communication between the channels and the liquid in which the structure is immersed.

9. A device as claimed in Claim 8, the external surface of which is increased by knurling or milling.

10. A device as claimed in Claim 1, in which a common additional heat exchange structure attached to the ribs or protuberances is constituted by a sheet of perforated metal having a good thermal conductivity soldered on to their ends.

11. A device as claimed in Claim 1, 2, 3 or any one of Claims 5 to 9, in combination with a coaxial deflector situated at a short distance from the external surface of the structure.

12. A device as claimed in Claim 1, in which the extremity of each of the ribs or protuberances is solid with a vertical metal conduit forming an auxiliary channel in which the liquid circulates by thermo-siphon effect without much vaporisation, irrespective of the tumultuous vaporisation which fills with vapour the main channels existing between the massive ribs or protuberances.

13. A device as claimed in Claim 12 in which the auxiliary channels are only



approximately fluid-tight laterally, being all of them enclosed by a coaxial deflector which does not participate to any great extent in the heat transfer.

- 5 14. A device as claimed in any one of the preceding claims, adapted to a hot body receiving heat from without, and containing the cooling liquid.

- 10 15. An electronic tube having an anode provided with a cooling device as claimed in any of the preceding claims.

16. A body giving off a large amount of heat to be evacuated with a high density

of thermal flux cooled by a device according to any one of the preceding Claims 1 to 15 14.

17. Devices for cooling bodies with a high calorific dissipation, substantially as described with reference to Figures 2 to 15 of the accompanying drawings. 20

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