July 16, 1968 N. ZUBER ET AL 3,392,781

VAPORIZING HEAT TRANSFER DEVICE

Filed Sept. 29, 1964

Fig. 1.

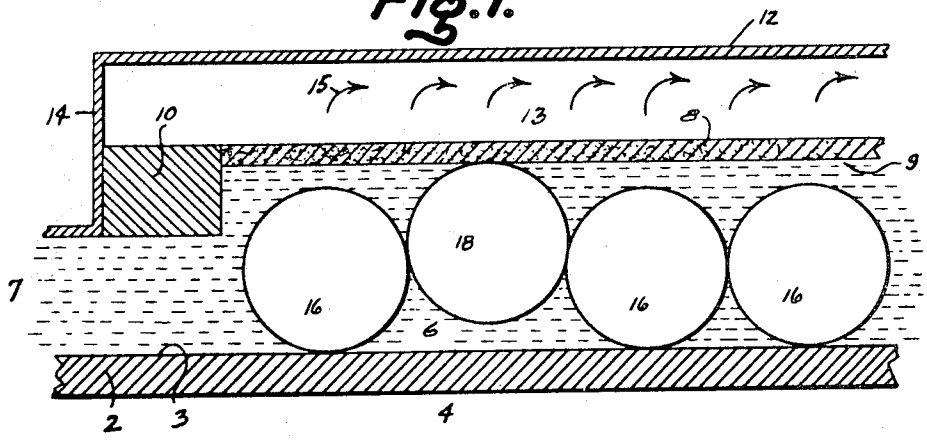


Fig. 2.

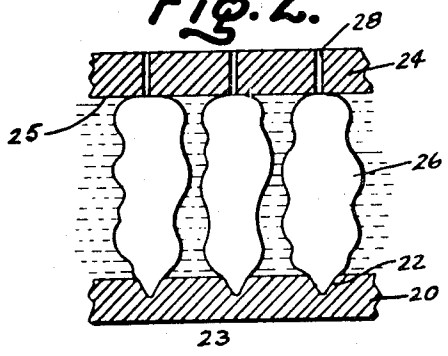
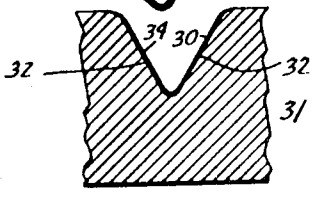


Fig. 3.



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VAPORIZING HEAT TRANSFER DEVICE

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9 Claims. (Cl. 165—133)

Our invention relates to heat transfer devices, and more particularly to a vaporizing heat transfer device that operates whether a gravitational field is present or not.

With the rapid advances in modern technology, the need arises for heat transfer devices that operate in the position wherein they are placed and continue to operate at the same efficiency while their position is being changed. These devices must therefore operate regardless of the gravitational effect, if any, that is present.

Heat transfer with a change of phase such as boiling is recognized to be one of the most effective ways of cooling. The problems inherent with a boiling system are those of vapor nucleation and vapor removal. Whereas, vapor generation and nucleation depend primarily on a temperature field, vapor removal depends on hydrodynamic forces. In boiling heat transfer, the vapor is removed from the surface by the action of gravity or shear forces. Where gravity is not present, vapor can be removed by the action of shear forces, as in a forced convection system or by the action of body forces as in a rotating fluid. However, both of these vapor removal schemes require pumps and piping, adding to the weight and power consumption of the system. These also involve cumbersome moving parts which take up extra space where space is at a premium.

Wicking material is also employed whereby the action of capillary forces maintains the liquid supply to the heating surface. The disadvantage here are the extreme slowness in the cooling and vapor generation rates that are attainable. The need then arises for a system with a high cooling and vapor generation rate wherein there are no moving parts and where the system operates in any gravitational environment, including one of a zero gravitational field. Applications for such a system would include cooling and temperature control, distillation of liquids for life support and vapor generation for power systems.

Our invention envisions a heat transfer device with fixed parts, which operates continuously regardless of whether a gravitational field is present or not.

The chief object of our invention is the provision of a heat transfer device which operates regardless of whether a gravitational field is present as the operation is taking place.

Another object of our invention is the provision of a heat transfer device having only stationary members with no movable parts.

Another object of our invention is the provision of a boiling heat transfer device which operates in any position under conditions of a zero gravitational field.

Another object of our invention is the provision of a boiling heat transfer device having means for forming vapor pockets at predetermined locations.

Another object of our invention is the provision of a heat transfer device having means for separating the vapor from the liquid regardless of the position the device is in at the time of separation, under a zero gravitational field.

These and other objects of our invention will be more readily perceived from the description which follows.

One of the features of our invention is a boiling heat transfer device, having fixed parts that operates at high efficiency in any position it is placed. This operation is effectuated by forces which operate regardless of whether a gravitational field is present or not.

The drawings illustrate preferred embodiments of our invention in which:

FIGURE 1 is a cross-sectional view of the heat transfer device of our invention;

FIGURE 2 is a cross-sectional view of a modification of the heat transfer device of our invention;

FIGURE 3 is an enlarged cross-sectional view of a modification of the nucleating centers of the heat transfer device of FIGURE 2.

FIGURE 1 illustrates an embodiment of the heat transfer device of our invention. The construction includes heating surface **2** whereby heat is transmitted from area **4** to the liquid contained within area **6** on the other side of surface **2**. Spaced from surface **2** is a separator **8** consisting of perforated material having small pores of a size such that surface tension prevents flow of a liquid such as water, ethylene glycol, glycerine or the like through the pores but gases or vapors will pass through the pores thus effectively separating the gas and liquids through which vapor passes. Adjacent separator **8** on one side thereof is wetting plug **10** so positioned to prevent escape of the vapor to be collected. Positioned in spaced relation to separator **8** and on the opposite sides thereof, from heating surface **2**, is wall **12** which in combination with end wall **14** forms a duct by which vapor is removed from the system.

Separator **8** is constructed of a porous material which easily passes vapor but which prevents the passage of liquid. Surface **9**, of separator **8**, preferably is coated with a nonwetting material, such as Teflon, to prevent the passage of liquid through the separator under the action of capillary forces. Alternatively, the separator is constructed of a membrane material of the permselective type that passes vapor but not liquid, such as silicone rubber membranes made by the General Electric Company, to achieve the same results.

In operation, liquid enters through opening **7** filling area **6**, whereby it comes into contact with side **3** of the heating surface **2**. Heat is transmitted through surface **2** and thereby to the layer of liquid against side **3**. As this heat is transmitted through surface **2**, bubbles or small air pockets begin to form on side **3** of surface **2** which cling to surface **3** by surface tension forces. As these bubbles grow by the formation of more vapor, the liquid directly above them is constantly being forced out of the way. The momentum of this liquid being forced out of the way combined with the decrease in pressure directly above a bubble eventually sucks the bubble up to surface **8** and as illustrated by bubble **18** in FIGURE 1. The vapor within the bubble then passes through perforated surface **8** into duct **13**, as shown by arrows **15**, to be withdrawn from the system and employed as desired. The liquid is prevented from being drawn through the perforated surface, as aforementioned, by the nonwetting material on lower surface **9** of separator **8**. Wetting plug **10** is positioned so that when bubbles **18** reach separator **8** they are forced into contact with separator **8** to be properly withdrawn from the system. That is, the bubbles will not be able to pass out of the device past wetting plug **10** and will be forced against separator **8** by their own momentum, as pointed out above, and by the crowding effect of other bubbles. Wetting plug **10** thereby directs the proper escape of vapor bubbles **18** as they are being extracted through separator **8** from the system. It will be appreciated that gravity in no way affects our heat transfer device since the bubbles pass from heating surface **2** to cooler separator surface **8** by means of momentum forces and not by gravitational forces.

In FIGURE 2 there is shown a modification of the heat transfer device of FIGURE 1. Provided within heating surface **20** are nucleating centers **22** consisting of either V-shaped cavities, or reentrant or other suitable

indentations or grooves within the heating surface. Because of their construction these grooves trap vapor within their pockets or act as nucleating centers thereby providing exact areas wherein the bubbles form. This prevents the bubbles from forming merely at random along the heating surface. In FIGURE 2 the vapor consists of a series of bubbles which form together thereby forming a jet between the two surfaces, heating surface **20** and separator **24**. Jets **26** permit the constant flow of vapor between heating surface **20**, with nucleating pockets **22** therein, and separator **24**, to be easily withdrawn from the system. Separator **24** is solid in construction having precise perforations **28** therein which are preferably aligned with nucleating centers **22** to draw off the vapor **26** as it is being formed. Lower surface **25** of separator **24** is coated with a nonwetting material to prevent the escape of liquid therethrough. Alternatively, surface **25** may only be coated with a nonwetting material adjacent perforations **28** and a wetting material or left uncoated on the remainder of surface **25** to force the vapor jets to cling to surface **25** aligned with apertures **28** for ease in removal of the vapor.

It will be appreciated the separator of FIGURE 2 may be employed in FIGURE 1 or vice versa with equal efficiency. It is further noted that nucleating centers **22** may be employed in the device of FIGURE 1 with equal effectiveness.

In operation, vapor pockets form within nucleating centers **22** since they are the closest to the area **23** from where the heat is being generated. It is also noted that by the use of nucleating centers **22** the greatest heated surface area is brought into proximity with the liquid. As vapor forms within nucleating center **22**, it continues to grow in the same way as the bubbles of FIGURE 1. The growth is rapid and the multiplicity of bubbles being formed within the nucleating center creates a jet of bubbles in the form of a continuous vapor stream between surface **20** and separator **24**, where it is withdrawn through openings **28** from the system. This jet action permits the separation distance between surface **20** and separator **24** to be large without imparting the efficiency of our system.

In actual practice the first bubble formed at center **22** will grow and the liquid directly above them is constantly forced out of the way. The combination of the momentum of this liquid and the decrease of pressure directly above the bubble will eventually suck the bubble up to surface **24** at opening **28** in a similar way to the operation of bubble **18** in FIGURE 1. A succession of bubbles will be formed at center **22** and will coalesce to form a continuous vapor stream **26** between center **22** and opening **28**.

FIGURE 3 illustrates an enlarged view of a nucleating center as shown in FIGURE 2. This center **30** consists of two sloping side walls **32** forming a V-shaped groove within heating surface **31**. A thin layer of nonwetting material **34** such as "Teflon" is applied to the interior of the nucleating center **30** to prevent the liquid from adhering and thus induce the vapor to form therein. It is noted that by the V-shaped configuration as aforementioned, the intensity of the heat forming the vapor is concentrated to thereby increase the vapor forming capabilities of the nucleating center. Thus, by the employment of the nucleating centers, vapor can be formed where desired with great facility.

It will be appreciated that the heat transfer device we disclosed operates in any position regardless of any gravitational or other forces present since it operates by momentum principles unrelated to weight phenomena.

It is now apparent that our invention attains the objectives set forth. Apparatus embodying our invention is sturdy in construction and well adapted for use in conjunction with both atmospheric and outer space environments. Ease of operation because of the lack of moving parts makes our device extremely adaptable to a multiplicity of applications.

Specific embodiments of our invention have been illustrated but the invention is not limited thereto since many modifications may be made by one skilled in the art and the appended claims are intended to cover all such modifications as fall within the true spirit and scope of our invention.

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

1. A device for forming and separating vapor comprising

a first surface through which heat travels to generate vapor within a liquid in contact therewith, which vapor travels in a direction away from said surface by momentum forces unaffected by gravitational forces, and

a porous surface to which the momentum forces propel the generated vapor and being of a nature to separate the vapor from the liquid, said porous surface being spaced from said first surface to form a passageway which is filled with liquid to normally contact both surfaces.

2. A device for forming and separating vapor in a zero gravitational field comprising

a nucleating surface through which heat travels to generate vapor thereon within a liquid in contact with said nucleating surface, which vapor travels in a direction away from said surface by momentum forces, and

a porous surface to which the momentum forces propel the generated vapor being of a nature to separate the vapor from the liquid, said porous surface being spaced from said nucleating surface to form a passageway wherein the liquid flows which is filled with liquid to normally contact both surfaces.

3. A device for forming and separating vapor comprising

a nucleating surface through which heat travels to generate vapor thereon within a liquid in contact therewith, wherein said nucleating surface has means defining indentations therein to cause vapor to form in said indentations, which vapor then travels in a direction away from said surface by momentum forces, and

a porous surface to which the momentum forces propel the generated vapor having a nonwetting surface on the side toward the nucleating surface to separate the vapor from the liquid, said porous surface being spaced from said nucleating surface to form a passageway which is filled with liquid to normally contact both surfaces.

4. A device for forming and separating vapor comprising

a first surface through which heat travels to generate vapor thereon within a liquid in contact therewith, wherein said first surface contains V-shaped nucleating centers therein to cause the formation of vapor in said indentation which vapor then travels in a direction away from said first surface by momentum forces unaffected by gravity, and

a porous surface to which the momentum forces propel the generated vapor to separate the vapor from the liquid, being coated with a nonwetting substance to aid in the separation process, said porous surface being spaced from said first surface to form a passageway wherein the liquid flows.

5. A device for forming and separating vapor comprising

a first surface through which heat travels to generate vapor thereon within a liquid in contact therewith, wherein said first surface contains nucleating centers therein to cause the formation of vapor in said centers, to form vapor jets which travel in a direc-

tion away from said first surface by momentum forces unaffected by gravity, and

a second surface to which the momentum forces propel the generated vapor jets, having apertures therein to separate the vapor from the liquid, said surface being coated on the side proximate the liquid adjacent the apertures with a nonwetting substance to prevent the passage of liquid through said surface, said porous surface being spaced from said first surface to form a passageway wherein the liquid flows.

6. A device for forming and separating vapor in a zero gravitational field comprising

a nucleating surface through which heat travels to generate vapor thereon within a liquid in contact therewith, wherein said surface contains grooves coated with a nonwetting substance to cause the formation of vapor in said grooves, which vapor then travels in a direction away from said nucleating surface by momentum forces, and

a separaing surface to which the momentum forces propel the generated vapor, having apertures therein to separate the vapor from the liquid, said surface being coated on the side proximate the liquid with a nonwetting substance to prevent the passage of liquid therethrough, said porous surface being spaced from said nucleating surface to form a passageway wherein the liquid flows.

7. A device for forming and separating vapor comprising

a first surface through which heat travels to generate vapor thereon with a liquid in contact therewith, wherein said first surface contains V-shaped nucleating centers therein to cause the formation of vapor in said indentation which vapor then travels in a direction away from said first surface by momentum forces unaffected by gravity,

a porous surface to which the momentum forces propel the generated vapor to separate the vapor from the liquid, being coated with a nonwetting substance to aid in the separation process, said porous surface

being spaced from said first surface to form a passageway wherein the liquid flows, and

means adjacent said porous surface for preventing the flow of bubbles from between said surfaces.

8. A device for forming and separating vapor comprising

a first heat conducting surface through which heat travels to generate bubbles in a liquid which is in contact with said surface, said vapor being moved by momentum forces unaffected by gravity in a direction away from said surface, and

a separating surface allowing said vapor but not said liquid to pass through it so that said vapor is separated from said liquid.

9. A device for forming and collecting vapor comprising

a first heat conducting surface through which heat travels to cause bubbles to generate in a liquid located in contact with said surface, said vapor travelling in a direction away from said surface and impelled by momentum forces and unaffected by gravitational forces,

a separating means comprising a porous surface spaced from said first surface to form a passageway for said liquid and to which vapor travel and which passes vapor but not liquid, and

a collecting means surrounding the other side of said porous surface for and conducting the vapor away from said porous surface.

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