

DEVICE FOR COOLING A LIQUID

FIELD OF THE INVENTION

[0001] The present invention generally relates to a heat transfer device, and more particularly to a device for cooling a liquid.

BACKGROUND OF THE INVENTION

[0002] The vacuum of space effectively acts as a radiant black body, drawing radiant energy from warmer objects. The effective sky temperature on any night is dependent on a number of factors, such as cloud cover and the moisture content of the air. When the sky is cloudy or when there is a relatively large amount of water vapour in the air, the effective sky temperature will be higher. However, particularly on clear, dry nights the effective sky temperature can be very low, drawing very large amount of heat from the earth to the vacuum of space through this radiant exchange.

[0003] Water vapor and other gases in the atmosphere absorb some of the heat re-radiating from the earth and thus create a greenhouse effect. Heat radiation is the electromagnetic waves in the infrared spectrum. The radiation of heat from one surface to a cooler surface is related to the temperature difference and emissivity of the surface. Different material, surface properties and colors give the surface different emissivities.

[0004] Emissivity is the ratio of the radiation intensity of a non black-body to the radiation intensity of a black body. This ratio is always less than one. The emissivity characterizes the radiation or absorption quality of non black-bodies. Emissivity varies with temperature and also varies throughout the spectrum.

[0005] Cooling using conventional air-conditioners consumes a great amount of energy. Alternate technologies such as cooling using a radiant roof, have been well documented. See for example, WhiteCap™ Roof Spray Cooling, M. Martin and P. Berdahl 1984. “Characteristics of Infrared Sky Radiation in the United States,” Solar Energy, Vol. 33, pp. 321-326. However, almost all the radiation cooling technologies have suffered from the influence of wind convection and vapor condensation, and thus are unable to achieve cooling temperature of water close to the dew point. Moreover, almost all existing technologies require that the roof and/or building be built with special material and specifications. This reduces the applications that use night sky radiation cooling.

[0006] From the foregoing disclosure and the following more detailed description of various preferred embodiments it will be apparent to those skilled in the art that the present invention provides a significant advance in the technology of heat transfer devices. Particularly significant in this regard is the potential the invention affords for providing a high efficiency, low cost heat transfer device for cooling liquids. Additional features and advantages of various preferred embodiments will be better understood in view of the detailed description provided below.

SUMMARY OF THE INVENTION

[0007] In accordance with a first aspect, a heat transfer device for cooling a liquid comprises a tube having a first end and a second end, a heat transferring panel located within the tube, wherein the heat transferring panel has a coating having a high emissivity, and a pipe adapted to carry the liquid, extending into and sealed off from the tube. The pipe contacts the heat transferring panel. At least a partial vacuum is maintained in the tube preferably with significant low moisture content.

[0008] From the foregoing disclosure and the following more detailed description of various preferred embodiments it will be apparent to those skilled in the art that the present invention provides a significant advance in the technology of heat transfer devices. Particularly significant in this regard is the potential the invention affords for providing a heat transfer device with improved liquid cooling properties. Additional features and advantages of various preferred embodiments will be better understood in view of the detailed description provided below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Fig. 1 shows a heat transfer device with a pipe for carrying a liquid in accordance with a preferred embodiment.

[0010] Fig. 2 is a cross section view taken along line 2-2 in Fig.1 showing the position of the pipe with respect to a heat transferring panel.

[0011] Fig. 3 shows an alternate preferred embodiment of a heat transfer device with a U-shaped pipe.

[0012] Fig. 4 is a cross section view taken along line 4-4 in Fig.3 showing the position of the pipe with respect to a heat transferring panel.

[0013] Fig. 5 shows another alternate preferred embodiment of a heat transfer device showing a plurality of interconnected tubes and pipes.

[0014] Fig. 6 is a schematic diagram of use of a heat transfer device in a liquid cooling arrangement.

[0015] Fig. 7 shows a preferred arrangement of a heat transfer device mounted on a slanted roof with the heat transferring panel facing the night sky.

[0016] It should be understood that the appended drawings are not necessarily to scale, presenting a somewhat simplified representation of various preferred features illustrative of the basic principles of the invention. The specific design features of the heat transfer device as disclosed here, including, for example, the specific dimensions of the heat transfer panel, will be determined in part by the particular intended application and use environment. Certain features of the illustrated embodiments have been enlarged or distorted relative to others to help provide clear understanding. In particular, thin features may be thickened, for example, for clarity of illustration. All references to direction and position, unless otherwise indicated, refer to the orientation illustrated in the drawings.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] It will be apparent to those skilled in the art, that is, to those who have knowledge or experience in this area of technology, that many uses and design variations are possible for the heat transfer device disclosed here. The following detailed discussion of various alternative and preferred features and embodiments will illustrate the general principles of the invention with reference to a device suitable for use in cooling a liquid. Other embodiments suitable for other applications will be apparent to those skilled in the art given the benefit of this disclosure.

[0018] Fig. 1 shows a heat transfer device 10 comprising a tube 12 having a first end 40 and a second end 42 opposite the first end, and a pipe 16 which extends into the tube 12. In the preferred embodiment shown in Fig. 1, the pipe enters the tube from the first end 40 and exits the tube at the second end 42. In accordance with a highly advantageous feature, a partial vacuum is maintained in the tube free of water vapor. Preferably the pressure within the tube is as low as possible, and less than 0.1 Pa. The tube 12 is preferably made of glass or other similar material having high transmissivity over a large spectrum range, including the far infrared region. The tube 12 encases a heat transferring panel 14 coated with a coating 33 comprising a material having high emissivity. Pipe 16 extends through the tube and contacts the heat transferring panel 14 such that a very good thermal contact is established between them. A liquid medium, preferably water or water with anti-freeze additives, flows through the pipe. One example of a suitable antifreeze additive is propylene glycol.

[0019] In accordance with a highly advantageous feature, the tube 12 preferably has high transmissivity, preferably at least 80%. Preferably, the tube is transparent in the visible spectrum, and is highly transparent to infrared wavelengths, especially those between 6 μ m to 14 μ m, and most preferably between 8 μ m and 12 μ m. The tube 12 can be made of quartz glass or borosilicate glass, for example, which is of sufficient mechanical strength to withstand the weather elements such as wind, snow, hail and sand storm. The tube 12 may also be made of chalcogenide glass which is transparent to even higher infrared frequencies than quartz glass-up to 15 μ m, for example. Chalcogenide glass is commonly used in thermal imaging appliances and can be moulded and extruded easily.

[0020] The near vacuum in tube 12 results in very minimum convection and conduction heat transfer within the tube 12. The heat transfer device 10 consists of the heat transferring panel 14 and the pipe 16, which is insulated by insulation 18 around the pipe 16 at both ends 40, 42 of the tube 12 to reduce conduction heat transfer. The dominant mode of heat transfer would be through radiation.

[0021] The tube 12 is of diameter between 30mm and 150mm, and most preferably between 50mm and 100mm. The length of the tube 12 is preferably between 500mm and 2000mm. Preferably the heat transferring panel 14 is a good thermal conductor, having a thermal conductivity K of at least 200W/(m·K). Examples of suitable materials for the heat transferring panel comprise a metal such as copper, aluminum, or an alloy of either copper or aluminum. The coating 33 of the heat transferring panel 14 has high emissivity, for example at least 0.8. Spectral emissivity can reach 0.95 for some oxides and paints. Examples of materials with high spectral emissivity are carbon black, titanium oxide, aluminium oxide and

many paints. High emissivity allows the heat transferring panel 14 to emit heat in the form of electromagnetic waves to a lower temperature body, i.e., to the tube away from the pipe.

[0022] The heat transferring panel 14 is usually oriented to face the night sky while avoiding facing obstacles such as buildings or trees. Since the night sky is of lower temperature than the heat transferring panel 14, heat is radiated from the heat transferring panel 14 to the night sky. The heat transferring panel 14 hence removes heat away from the liquid flowing in the pipe 16. The pipe 16 is preferably made of the same material as the heat transferring panel 14.

[0023] The peak emission wavelength of a radiating blackbody is governed by the Wien's law which can be calculated as 2898 (micron)/blackbody temperature (K). For a radiating body of 30°C, or 303K, the peak emission wavelength is 9.56 micron.

[0024] The radiating heat transfer rate is governed by the Stefan-Boltzmann law:

$$P = e\sigma A(T^4 - T_c^4)$$

where P = net radiated power;

e = emissivity (=1 for ideal radiator);

A = radiating area;

T = temperature of radiator;

T_c = temperature of surrounding; and

σ = Stefan's constant = $5.6703 \times 10^{-8} \text{ w/m}^2\text{K}^4$.

[0025] When there is no cloud and the night sky is clear, the night sky temperature can be as low as -70°C or 203K . The average night sky temperature can be as low as 250K . The difference in temperature between the radiator and the night sky is therefore about 50K . Under such conditions, it is possible to radiate more than 200W of energy to the night sky for every square meter of radiating surface. It is highly possible that the liquid in the pipe 16, if it is pure water, will be frozen due to the rapid heat transfer. Due to the encapsulation of the heat transferring panel 14 by the tube, convection and conduction effects are significantly reduced.

[0026] Figs. 3-4 show another preferred embodiment of a heat transfer device 10 with a U-shaped pipe 22. The pipe 22 enters the tube 12 through the first end 40 and also exits the tube from the same end. The heat transfer device 10 consists of the heat transferring panel 14 and the U-shaped pipe 22, which is insulated by insulators 18 at both ends of the U-shaped pipe 22 which is protruding from the tube 12 to minimize conduction heat transfer. As in Fig. 1, the dominant mode of heat transfer would be through radiation.

[0027] Fig. 5 illustrates a heat transfer device 10 comprising a heat transferring array 24 made up of a plurality of tubes 12 each having a first end and a second end, a plurality of heat transferring panels 14 each located within a corresponding tube, and a plurality of pipes 16 adapted to carry the liquid, extending into and sealed off from the corresponding tube. Each of the plurality of pipes contacts its corresponding heat transferring panel. Each of a plurality of connecting pipes 26 connects one of the plurality of pipes to another of the plurality of pipes. Flow of liquid through the array starts at inlet 28, runs through the plurality of pipes and exits at outlet 30. The liquid cools significantly as it travels along this flow path.

[0028] Fig. 6 shows a liquid cooling arrangement, where the outgoing cool liquid from the heat transfer device 10 can optionally be connected to a tank 32. The tank stores the liquid. Preferably the tank is in fluid communication with the pipe. A circulating pump 36 is positioned between the tank and the pipe and is adapted to pump liquid from the tank to the pipe. A controller 34 controls when the pump pumps liquid to the pipe. All the pipes and tanks are suitably insulated to prevent heat gain.

[0029] The cool liquid in the tank 32 can be used for numerous applications such as air-conditioning and refrigeration. The controller 34 receives temperature measurements of the heat transfer device 10 and the tank 32. One of the conditions when the controller 34 activates a circulating pump 45 is when the temperature of the heat transfer device 10 is sufficiently lower than the cool liquid. The warm liquid is fed into the heat transfer device 10 while the cool liquid is returned to the tank 32. No circulation of liquid takes place when the heat transfer device is warmer than the tank 32, such as can be the case in the daytime.

[0030] Referring to Fig. 7, the heat transfer device 10 can be placed on a support 38 such as on the roof or on the ground. The heat transfer device 10 is inclined at an angle to ensure that condensate does not stay on an outer part of the heat transfer device. The heat transferring panels 14 should preferably be facing the night sky. There should not be any obstacles, such as buildings or trees between the device 10 and the night sky, in order to enhance heat transfer.

[0031] From the foregoing disclosure and detailed description of certain preferred embodiments, it will be apparent that various modifications, additions and other alternative embodiments are possible without departing from the true scope and spirit of the invention.

The embodiments discussed were chosen and described to provide the best illustration of the principles of the invention and its practical application to thereby enable one of ordinary skill in the art to use the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.

CLAIMS

1. A heat transfer device for cooling a liquid comprising, in combination:
 - a tube having a first end and a second end;
 - a heat transferring panel located within the tube, wherein the heat transferring panel has a coating having an emissivity of at least 0.8; and
 - a pipe adapted to carry the liquid, extending into and sealed off from the tube, contacting the heat transferring panel;wherein at least a partial vacuum is maintained in the tube.
2. The heat transfer device of claim 1 wherein the tube is made of one of glass, quartz glass, borosilicate glass and chalcogenide glass.
3. The heat transfer device of claim 1 wherein the transmissivity of the tube is at least 80%.
4. The heat transfer device of claim 1 wherein the tube is transparent to wavelengths between 6 μ m and 14 μ m.
5. The heat transfer device of claim 4 wherein the tube is transparent to wavelengths between 8 μ m and 12 μ m.
6. The heat transfer device of claim 1 wherein the heat transferring panel comprises a metal.

7. The heat transfer device of claim 6 wherein the metal comprises one of aluminum, copper and an alloy thereof.
8. The heat transfer device of claim 1 wherein the heat transferring panel has a thermal conductivity of at least $200\text{W}/(\text{m}\cdot\text{K})$.
9. The heat transfer device of claim 1 wherein the coating comprises one of carbon black, paint, titanium oxide and aluminium oxide.
10. The heat transfer device of claim 1 wherein the partial vacuum comprises no more than 0.1 Pa.
11. The heat transfer device of claim 1 wherein the diameter of the tube is between 30 mm and 150 mm, and the length of the tube is between 500 mm and 2000 mm.
12. The heat transfer device of claim 1 wherein the pipe enters the tube from the first end, and exits the tube from the second end.
13. The heat transfer device of claim 12 further comprising insulation positioned around the pipe where the pipe enters the tube and exits the tube.
14. The heat transfer device of claim 1 wherein the pipe is U-shaped, and enters and exits the tube from the first end.

15. The heat transfer device of claim 1 wherein the pipe and the heat transferring panel comprise a same material.
16. The heat transfer device of claim 1 further comprising
- a plurality of tubes each having a first end and a second end;
 - a plurality of heat transferring panels each located within a corresponding tube; and
 - a plurality of pipes adapted to carry the liquid, extending into and sealed off from the corresponding tube, wherein each of the plurality of pipes contacts the corresponding heat transferring panel; and
- a plurality of connecting pipes, wherein each connecting pipe connects one of the plurality of pipes to another of the plurality of pipes.
17. The heat transfer device of claim 1 further comprising
- a tank for storing the liquid in fluid communication with the pipe;
 - a circulating pump positioned between the tank and the pipe adapted to pump liquid from the tank to the pipe; and
- a controller which controls when the pump pumps liquid to the pipe.