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(54) **SELF-PUMPING LIQUID AND GAS COOLING SYSTEM FOR THE COOLING OF SOLAR CELLS AND HEAT-GENERATING ELEMENTS**

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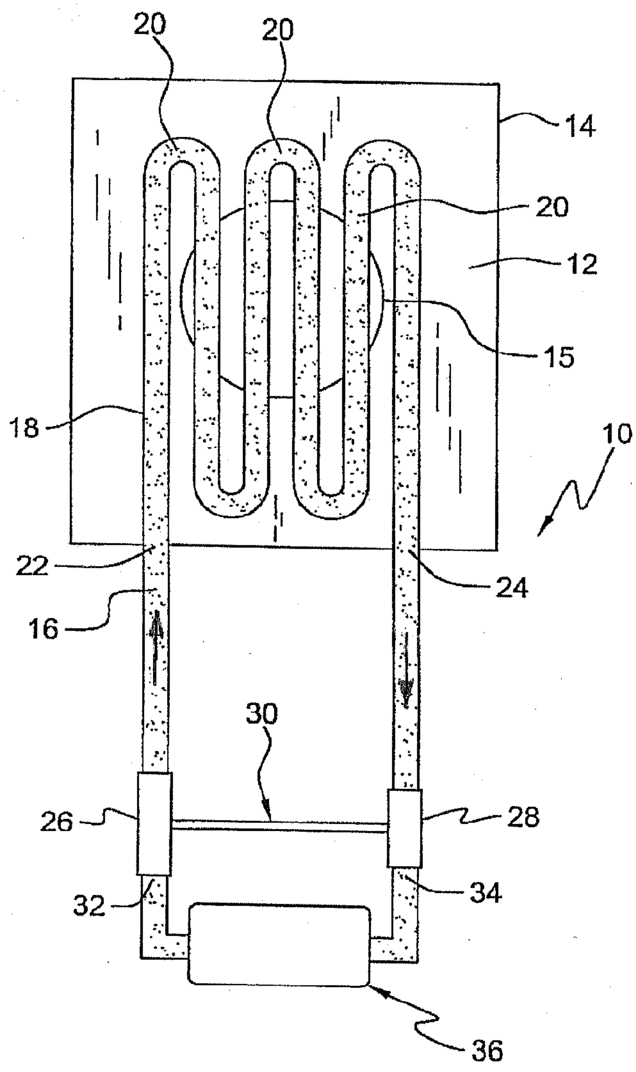
(57) **ABSTRACT**

A self-pumping liquid and gas cooling system for the cooling of solar cells and heat generating elements. A method for the self-pumping of liquid and gas coolants utilizes the cooling system. The essentially closed coolant system incorporates a heat exchanger having a length meandering tubing passing therethrough the opposite ends of which are, respectively, in communication with a driving pump and a return pump that are interconnected by a shaft. Hereby, tubing intermediate the circuit formed by the pumps extends through an evaporator structure containing the chip or heat-generating solar cell or cells.



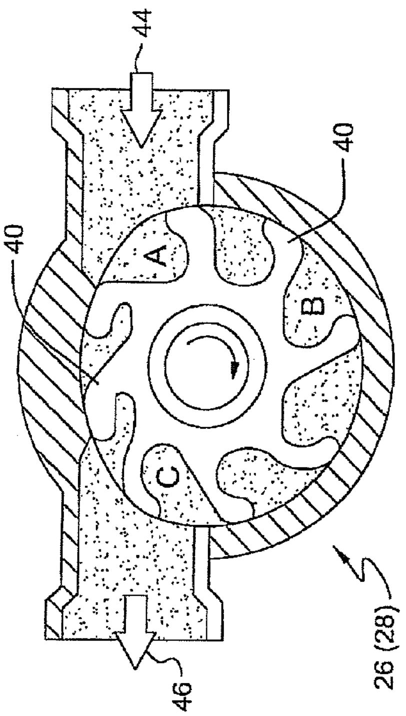


FIG. 2

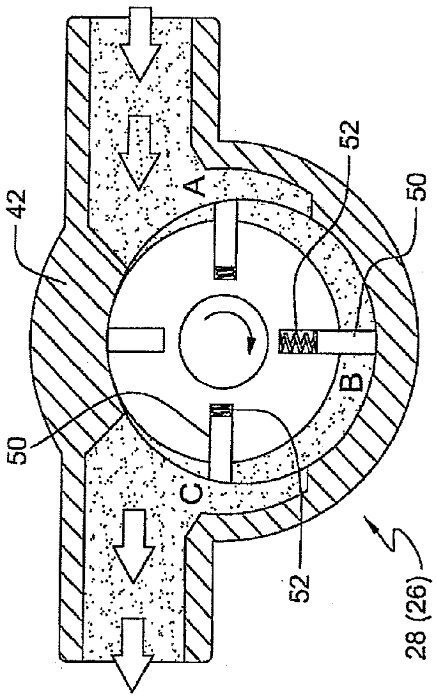


FIG. 3

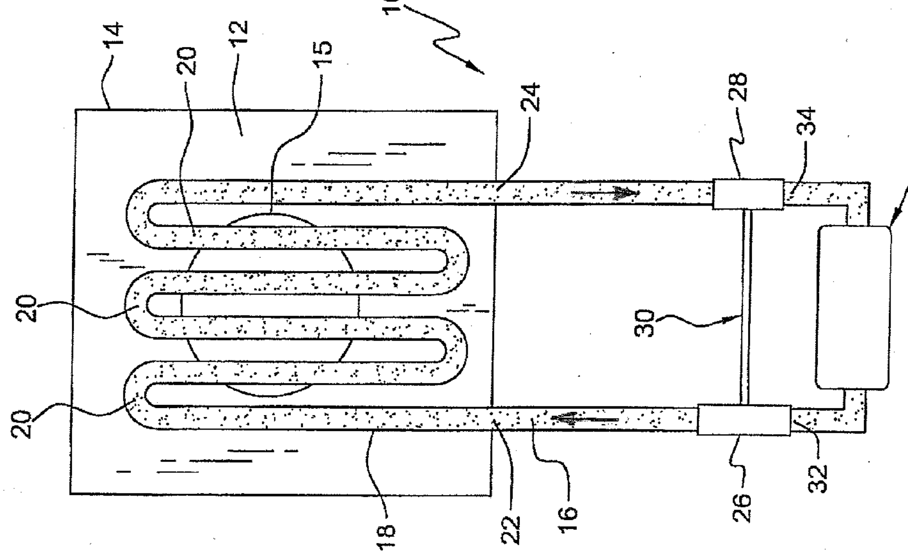


FIG. 1

SELF-PUMPING LIQUID AND GAS COOLING SYSTEM FOR THE COOLING OF SOLAR CELLS AND HEAT-GENERATING ELEMENTS

BACKGROUND

[0001] The present invention relates to a self-pumping liquid and gas cooling system for the cooling of solar cells and heat generating elements. Moreover, the invention is also directed to the provision of a method for the self-pumping of liquid and gas coolants utilizing a cooling system pursuant to the invention.

[0002] Solar cells, as well as other kinds of heat generating components or elements, such as semiconductor chips and electronic devices, inherently process a tendency to generate appreciable amounts of heat, the latter of which must of necessity be designated and removed in an efficient and economical manner, in order to avoid damaging or destroying these heat-generating and other ancillary elements.

THE PRIOR ART

[0003] At this time, pursuant to the current technology, there are available systems for diverse liquid-gas heat exchanger applications adapted to provide for semi-conductor chip cooling, which utilize thermally pumped liquid and gas flows through siphon cooling, during which a pump containing no moving components re-injects coolant into an evaporator for cooling a semiconductor chip or similar type of heat generating element.

[0004] The foregoing system, as presently known in the technology, is subject to various problems in that the pump that is employed therein requires the use of external power in implementing its operation. Furthermore, as is the condition encountered in all types of thermal siphons, that system is generally influenced, to a considerable degree, by the force of gravity and, resultingly necessitates a specific physical orientation of a radiator above an evaporator and a return pump at a location and in a particular positioning in which it can collect fluid and force it downwardly to some extent towards the evaporator.

[0005] As a consequence, although the prior art system functions generally satisfactorily, it is subject to various technical drawbacks and operative limitations and requires the supplying thereof with external energy, thereby significantly increasing the necessary expenditures in operating and installation costs.

SUMMARY OF THE INVENTION

[0006] In order to ameliorate or even possibly entirely eliminate the drawbacks and limitations that are encountered in the prior art, pursuant to the invention there is provided a system which, in a practical manner utilizes heat from the chip, for instance, an element such as a solar cell, in order to drive a pump in a manner analogous to the operation of a steam-driven pump or turbine. In effect, the pump capable of returning coolant to the evaporator from almost any physical orientation able to produce a partial vacuum, and which will draw coolant in an either up or down mode. Moreover, the pump can assist in producing a forcible circulation or coolant throughout the system, while being readily constituted of inexpensive and commercially available structural components. Additionally, the pump presently utilizes a closed circulating system for cooling solar cells that does not require a supply of any external power, inasmuch as the pump is operated or driven itself by any undesired or unwanted waste heat that is generated by the chip or solar cell or array thereof. Hereby the waste heat which tends to normally adversely effect the performance of the solar cell is employed by the system to improve the performance by cooling the chip or solar cell (or array).

[0007] In accordance with the invention, there is provided a system which affords an active cooling of a chip or solar cell or cells, or similar heat generating through the boiling of a coolant which drives an integral turbine/pump in order to circulate the coolant. In such an instance, pursuant to the invention turbine/pump units which are suitable can be constituted of inexpensive structures, such as, for example, commercially available beverage pumps, which can be sealed and coupled magnetically and which, in effect, are obtainable as off-the-shelf inexpensive components.

[0008] Pursuant to the invention, the essentially closed coolant system incorporates a heat exchanger having a length of meandering tubing passing therethrough the opposite ends of which are, respectively, in communication with a pump operating as a driving turbine and a return pump that are interconnected by a shaft. Hereby, the tubing intermediate the circuit formed by the pumps extends through an evaporator structure containing the chip or heat generating solar cell or cells, as described in further detail hereinbelow.

[0009] In essence, in order to operatively function, as required by the invention, the driving turbine which, as mentioned, may be of a pump structure similar to that of the return pump, but is of a somewhat larger size and, if necessary the turbine can drive a small DC motor as a generator or it can, in turn, drive a DC motor for the pump, enabling the turbine and return pump to be widely separated depending upon a specific physical application, or they may be mounted as close as possible.

[0010] Accordingly, it is an object of the present invention to provide a closed cooling system having a self-pumping liquid and gas cooling arrangement for implementing the cooling of heat-generating components, such as solar cells.

[0011] It is another object of the present invention to provide a method utilizing a self-pumping liquid and gas-cooling system for the cooling of heat generating components, such as solar cells in a highly efficient and inexpensive manner.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Reference may now be made to the following detailed description of the inventive system, taken in conjunction with the accompanying drawings; in which:

[0013] FIG. **1** illustrates a representative self-pumping cooling system for the cooling of heat-generating components pursuant to the invention shown generally in a diagrammatic representation;

[0014] FIG. **2** illustrates, on an enlarged scale, the detail of a representative flexible impeller pump which may be utilized in conjunction with the coolant system pursuant to the invention; and

[0015] FIG. **3** illustrates, on an enlarged scale, an example of a conventional vane pump which may be utilized in lieu of the flexible impeller pump of FIG. **2**, or in conjunction therewith.

DETAILED DESCRIPTION

[0016] Referring specifically to the closed coolant system pursuant to the invention, as illustrated in FIG. **1**, there is represented a cooling system **10** that includes a heat exchanger which may be constituted of an enclosed housing structure **14** and has a tubing arrangement **18** therein containing or filled with either water or any suitable coolant **16**, for example, such as methanol or a coolant solution marketed by 3M Corporation under the designation HFE-7000. In this connection, methanol is particularly suitable when maintained under an operating pressure of about 100 mm Hg. It is also possible to employ ammonia as a coolant, but may be somewhat hazardous to use unless the system is generated remotely from population centers.

[0017] Traversing the heat exchanger **12** is the closed-cycle tubing or piping system **18** of which coils or loops **20** meander therethrough, as illustrated in the drawing. The tubing may be embedded in an array of copper fins, which conduct heat to air, which may include a fan (not shown) blowing air through an opening **15** formed in the housing **14** of the heat exchange. The opposite ends **22**, **24** of the tubing **18** which extend outwardly from the heat-exchanger **12** each communicate, respectively with a driving turbine **26** and a return pump **28**. These components **26**, **28** are interconnected by means of a shaft **30** so as to be rotatable in unison. The tubing ends **32**, **34** projecting from the opposite sides of the turbine **26** and return pump **28** are then closed off beyond the turbine and return pump by extending into an evaporator arrangement **36** containing either a heated component which is to be cooled, such as a chip or a solar cell or plurality thereof, thereby completing the closed cooling system **10**.

[0018] Reverting in particular to the types of structures employed for, respectively, the turbine **26** and the pump **28**, these may be essentially constituted similarly in nature, such as illustrated in FIG. **2**, showing a flexible vane impeller pump **40**, or alternatively, may consist of a vane pump **42** as illustrated in FIG. **3** of the drawings, as elucidated in further detail hereinbelow.

[0019] Hereby, the pumps **26**, **28** are essentially positive displacement pumps, and as mentioned may be commercially available for the purpose of cooling the heat-generating elements or solar cells, such pumps being inexpensive by being formable from beverage-type pump structures, which can be sealed and coupled magnetically. The pumps can be constituted of self-priming pumps adapted to initiate start operation without the need for any external energy or generated partial vacuum, so as to be able to draw a coolant from practically any location, without being dependent upon gravity in order to return the coolant.

[0020] As illustrated in FIG. **2**, this is essentially shown as a flexible impeller pump **40**, which basically is a type of vane pump and the operation of which can be that of being driven by an outside motor (not shown) in a clockwise direction. Thus, cooling fluid will enter the pump from the right inlet **44**, displaced within the pump body **40** towards a further position and ultimately discharged at the left-hand position from outlet **46**. The pump is essentially self-priming in nature providing an almost continuous flow and can be essentially driven in either direction, as may be necessary.

[0021] Alternatively, as shown in FIG. **3** of the drawings, this pump may also be satisfactory in operation constituting an essentially commercial type of vane pump **42** having flexible impeller vanes **50** which form an eccentric axial pump, with the vanes **50** being moved or reciprocated radially inward and outward during rotation of the pump. Although this radial motion may be implemented during rotation, the vanes **50** can also be pushed or positively displaced radially outwardly by means of springs **52** (shown schematically) and, in operation, is similar in performance with the previously discussed flexible impeller pump **40** of FIG. **2**.

[0022] Assuming the impeller vane pump **42** or pump **40** is in an operational mode, with the fluid and gas entering from the right under pressure from the evaporator arrangement **36** in effect, the stucture containing the solar cells wherein the evaporator is basically a container for coolant into which there is conducted unwanted heat from the solar cells or chip, then the impeller of the pump must rotate in a clockwise direction as fluid and gas push through the chambers between the vanes thereof, whereby torque is delivered to the shaft. In the evaporator there are generated extensive amounts of gas and entrained fluid, and thus adapted to convey heat away from the chips or solar cells.

[0023] In order to utilize the torque which is generated for transmission, to the shaft **30** which is connected to the pump or turbine **26** is coupled to the second pump **28**, which may be similar in function either to that of FIG. **2** or FIG. **3**, and which injects condensed coolant back to the evaporator **36**. Although identical to the first mentioned pump or turbine **26**, the pump **28** must displace a lesser amount of fluid, and the pumping chambers thereof are according of a smaller dimension by utilizing the same type of pump housing having different and smaller rotor diameters interiorly thereof.

[0024] The reason the return pump **28** has a smaller pumping volume, resides in that the first pump, which is designated as the turbine **26**, has a significantly greater mechanical advantage, and since the return pump **28** pushes coolant into the evaporator, it must overcome the same pressure which turns the turbine or the first mentioned pump **26**. This may require a 4:1 or 10:1 ratio or aspect in order to assure a good operating performance, and which would be satisfactory inasmuch as the evaporator **36** generates large volumes of gas whereas the return pump **28** only needs to return condensed fluid, thereby ensuring that the cooling system **10** will not run out of fluid.

[0025] Inasmuch as the return pump **28** is self-priming, or generates a partial vacuum during operation, it can draw coolant from nearly anywhere and is not dependent upon gravity in order to return coolant.

[0026] With respect to the pump which serves as the turbine **26**, in effect the larger-sized pump, although possibly utilizing a rotor with the vanes as illustrated, a larger amount of vanes can also be utilized, noting that essentially the pump structure shown in FIG. **2** may be somewhat more advantageous than the radially extending or reciprocating vanes of FIG. **3** since a pump of that type generates a higher vacuum. However, these pumps are operated to rotate at a relatively slow pace, possibly less than 100 rpm, and there should theoretically be little or no leakage of gas past the vanes. Moreover, the material selected for the pump vanes is operated at elevated temperatures for a considerable amount of time, without the need for replacement and also some leakage of gas past the turbine vanes is acceptable, since an excess of a volume of gas is present relative to that of the cooling fluid.

[0027] As indicated, besides water, the coolant may be methanol or 3M's HFE-7000, with methanol being possibly more preferable, dependent upon need, since it is a higher performance coolant.

[0028] It is also noted that the turbine **26** and the return pump **28** can be mounted either closely together within the cooling system, or far apart depending upon size or particular application, and the turbine **26** can drive a small DC motor as a generator, and in turn, can drive a DC motor for the pump **28**.

[0029] The motors for the turbine and return pump can be magnetically coupled, as frequently implanted in motor-driven pumps, so that the entire cooling system **10** is totally sealed, while gravity is not considered to be an issue, as long as the return pump **28** is fitted with a small tube (not shown) that is connected to a pooled source of condensed fluid.

[0030] Moreover, in addition to the foregoing, the return pump **28** may be augmented, in an optional manner with a free-wheeling motor employed to be operated or driven for an unusual operating condition, during a start up condition, or during unforeseen operating conditions, but is not necessary to the invention. In the instance of cooling solar cells, electric power can be made readily available for the operation of such a free-wheeling motor without having to supply commercial electrical energy thereto.

[0031] Furthermore, the heat exchange does not need to be from liquid to air, but can be liquid to water in the heat exchanger arrangement **36**.

[0032] Moreover, it is also possible to provide a one way check path between the evaporator **36** and the return pump **28** in order to ensure that no fluid and gas will escape through the pump vanes. This, however, may not be absolutely necessary, depending upon the quality of the sealing structure employed for the vanes of both pumps **26**, **28**.

[0033] The coolant loop of the system which contains an environmentally electrically benign coolant, such as HFE-7000, prevents water being brought close to a chip or solar panel, even within a cabinet or rack mounting the solar chips, whereby any small leak encountered would not provide any adverse effects, except for the eventual minor loss of some cooling capacity.

[0034] Moreover, the heat generating element or elements, such as the solar cell or cells, should be embedded within the evaporator chamber for the best conduction of heat generated therefrom into the evaporator **36**, wherein the only constraint may be that the top surface of the solar cells are to be exposed to light to enable the functioning thereof. Light could also be directed thereto from either a natural exposure to sunlight or from a Fresnel lens by being bounced off a mirror, if it is desirable to provide an improvement in the cooling action.

[0035] Finally, any waste heat contained in the primary coolant can be pumped by the system into a suitable hot water system (not shown) which can be employed as washing or bathing water in the hot water system, or for heating the interior of a house or similar structures.

[0036] From the foregoing, it becomes readily apparent, that the present invention is directed to a novel and inexpensive cooling system utilizing self-pumping arrangements for the cooling of heat-generating components or solar cells.

[0037] While the present invention has been particularly shown and described with respect to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in forms and details may be made without departing from the spirit and scope of the present invention. It is therefore intended that the present invention not be limited to the exact forms and details described and illustrated, but fall within the scope of the appended claims.

What is claimed is:

1. A self-pumping liquid and gas coolant circulating system for the cooling of heat-generating elements, said system comprising:

a heat exchanger unit;

a tubing arrangement containing said coolant and having undulating tubing portions winding through said heat exchanger unit, inlet and outlet ends of said tubing arrangement extending outwardly from said heat exchanger unit;

a first circulating drive pump for conveying said coolant through said system having an inlet connected to the outlet end of said tubing arrangement;

a second circulating return pump for conveying said coolant through said system having an outlet connected to the inlet end of said tubing arrangement, said pumps being interconnected for mutual operation;

an evaporator containing at least one said heat-generating element being located intermediate said pumps, wherein a tubing section connects an inlet of said evaporator with an outlet of said first circulating pump, and a further tubing section connects said outlet of said evaporator with an inlet of said second circulating pump, wherein there is formed a closed circulating path for said coolant through said cooling system.

2. A system as claimed in claim **1**, wherein said first and second circulating pumps are operatively interconnected by a shaft for rotation in unison with each other.

3. A system as claimed in claim **1**, wherein said first and second circulating pumps are magnetically interconnected for rotation in unison with each other.

4. A system as claimed in claim **1**, wherein said first circulating pump has a larger flow volume than said second circulating pump.

5. A system as claimed in claim **4**, wherein said flow volume of said first circulating pump is in a range of about 4:1 to 10:1 that of the second circulating pump.

6. A system as claimed in claim **1**, wherein said first and second circulating pump are impeller vane pumps.

7. A system as claimed in claim **1**, wherein said first circulating pump is a turbine and said second circulating pump is an impeller vane pump.

8. A system as claimed in claim **6**, wherein said impeller vane pumps have, selectively, flexible vanes or radially oscillatable vanes.

9. A system as claimed in claim **1**, wherein said coolant is selectively constituted of water, or methanol, or mixtures thereof.

10. A system as claimed in claim **1**, wherein said coolant is constituted of ammonia.

11. A method for the cooling of heat-generating elements by self-pumping liquid and as coolant circulating system, said method comprising:

providing a heat exchanger unit having a tubing arrangement containing said coolant and having undulanting tubing portions winding through said heat exchanger unit inlet and outlet ends of said tubing arrangement extending outwardly from said heat exchanger unit:

having a first circulating drive pump conveying said coolant from the outlet end of said tubing arrangement;

conveying said cooling from said first circulating pump to a second circulating pump operatively and interconnecting said first and second pumps;

interconnecting an evaporator containing at least one said heat-generating element intermediate said pumps, wherein a tubing section connects said evaporator with said first circulating pump, and a further tubing section connects evaporator with said second circulating, so as to form a closed circulating path for propagating said coolant through said cooling system, whereby coolant heated to a gaseous state by said at least one heat-generating element in said evaporator is conducted by said second pump to said heat exchanger and cooled into a liquid state therein, and conveyed to said first pump and recirculated through said evaporator for absorption of heat from said at least one heat-generating element.

12. A method claimed in claim **11**, wherein said first and second circulating pumps are operatively interconnected by a shaft for rotation in unison with each other.

13. A method as claimed in claim **11**, wherein said first and second circulating pumps are magnetically interconnected for rotation in unison with each other.

14. A method as claimed in claim **11**, wherein said first circulating pump possesses a larger flow volume then said second circulating pump.

15. A method as claimed in claim **11**, wherein said first and second circulating pump are impeller vane pumps.

16. A method as claimed in claim **11**, wherein said first circulating pump is a turbine and said second circulating ump is an impeller vane pump.

17. A method as claimed in claim **11**, wherein said coolant is constituted of selectively water or methanol, or mixtures thereof.

18. A method as claimed in claim **11**, wherein said coolant comprises ammonia.

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