The invention relates to a thermal management device intended to collect the heat dissipated by a group of dissipative equipment of a spacecraft in an evaporation zone before discharging this heat to cold space via a condensation zone, situated in the region of the radiators. The evaporation zone and the condensation zone each consist of at least one heat-exchange part comprising a network of a plurality of compact heat-exchange elements distributed over their respective heat-exchange surface and connected in series and/or in parallel by the tubes of the thermal fluid circulation means.

A device such as this is particularly intended for telecommunications satellites.
Circulation of fluid for removing thermal energy to Space

Reverse circulation of fluid

Fig. 8
Fig. 9
THERMAL MANAGEMENT DEVICE FOR A SPACECRAFT

PRIORITY CLAIM

[0001] This application claims priority to French Patent Application Number 09 01031, Thermal Management Device for a spacecraft, filed on Mar. 6, 2009.

FIELD OF THE INVENTION

[0002] The field of the invention is that of thermal management devices for a group of dissipative equipment of a satellite and more generally of a spacecraft.

BACKGROUND OF THE INVENTION

[0003] In general, satellites comprise a set of equipment intended to perform the functions of the missions for which they are sent into space, notably observation or telecommunications missions. This equipment consumes and dissipates a substantial amount of energy that has to be removed from the structure of the satellite so that this equipment remains within a nominal temperature range. To do that, the satellites are equipped with a thermal management device notably comprising thermal fluid circulation pipes, commonly known as heat pipes, and fluid loops allowing the heat of the dissipative equipment to be transported to radiative elements that radiate the thermal energy into space. In satellites, it is common practice to use the structural panels on which to install the radiative surfaces. In such configurations, the thermal energy that can be removed is limited by the size of the structural panels. Satellites are sized, amongst other considerations, in such a way as to minimize the mass of the thermal management system, the dimensions of the associated elements having to be limited so as to allow them ultimately to be integrated into the satellite, the size associated with the latter also having to be limited so that it can be best integrated into the launcher. To improve the removal of heat into space, it is known practice to install on the satellite double-sided or single-sided deployable radiative surfaces which are able to radiate at a higher or lower temperature in order to remove some of the dissipated heat and thus guarantee that the equipment is kept at admissible temperature levels. However, a deployable system such as this makes the structure of the satellite heavier and increases the size and complexity of the cooling device through the presence of the control means and mechanisms for deploying the panels.

[0004] A thermal management device installed on board a spacecraft and described in patent application FR2912955A1 is known. That device allows the dissipative equipment to be thermally decoupled from their associated radiators and allows the areas of the radiative heat exchange surfaces to be varied according to the amount of thermal energy to be removed into space by means of a fluid circulation circuit comprising several hydraulic branches that can be isolated from one another. That system has disadvantages. The hydraulic circuit of the thermal management device, particularly the condensation zone in contact with the radiative surface directed towards space, is exposed to micrometeorite attack. For that reason, it is known practice to improve the reliability of the thermal management device either by thickening the heat-exchange elements in the condensation zone and, if necessary, those in the evaporation zone, or by installing an entirely redundant hydraulic circuit. Both approaches carry a heavy weight penalty. Furthermore, when the evaporation zone and the condensation zone consist of continuous tubular systems, the pressure drops may be not insignificant, notably when an all-series configuration is given preference in order to avoid thermo-hydraulic instabilities, and this dictates additional compression work in order to achieve the high-temperature radiation objective. This has an impact on the mass of the device, on the energy consumption, and represents an integration constraint when the evaporators and condensers have to have redundancy for reliability reasons, that being true notably on account of the multitude of tubes under the equipment. Finally, present-day structural panels are thermally conductive which means that it is inconceivable for equipment to be mounted on the internal face thereof while at the same time expecting thermal energy to be removed from the higher-temperature external face without having an impact on the temperature level of the equipment opposite it inside the satellite. That means that panels have to be superposed in order to provide the necessary thermal decoupling or that additional deployable structures have to be used, both solutions significantly increasing the overall weight.

SUMMARY OF THE INVENTION

[0005] The objective of the invention is to achieve the reliability of objectives of a satellite thermal management device while at the same time optimizing its efficiency and minimizing its mass.

[0006] For that, the invention relates first of all, in general, to a thermal management device intended to collect the heat dissipated by a group of dissipative equipment of a spacecraft in an evaporation zone before discharging this heat to cold space via a condensation zone, spacecraft comprising a plurality of structural panels and the thermal management device comprising means of circulating thermal fluid connecting, in a closed loop, at least the evaporation zone and the condensation zone, the evaporation zone constituting a first heat-exchange surface for exchanging heat, directly or indirectly via other heat-transfer means, with the dissipative equipment associated with the structural panels and the condensation zone constituting a second heat-exchange surface for exchanging heat, directly or indirectly via other heat-transfer means, with radiators radiating into space.

[0007] Advantageously, the evaporation zone and/or the condensation zone consists of at least one heat-exchange part comprising a network of a plurality of compact heat-exchange elements distributed over their respective heat-exchange surface and connected in series and/or in parallel by the tubes of the thermal fluid circulation means.

[0008] The evaporation zone constitutes a first heat-exchange surface that can be connected directly and/or indirectly by other thermal means to the dissipative equipment. The condensation zone constitutes a second heat-exchange surface that can be connected directly and/or indirectly via other thermal means with the radiative surfaces. The compact heat-exchange elements may be in direct contact with the dissipative equipment or in contact with the heat-transfer means connected to the equipment, such as heat pipes and/or fluid loops.

[0009] What is meant by "compact heat-exchange element" are the elements commonly known as evaporators in the evaporation zone and condensers in the condensation zone.

[0010] The use of the compact heat-exchange elements makes it possible to limit the area of surface to be protected...
from micrometeorite activity, and therefore the mass of the exchangers and to minimize the thermal gradient between the fluid circulating through the evaporation zone and the dissipative equipment, on the one hand, and between the fluid circulating in the condensation zone and the radiative surfaces, on the other. Further, their compactness means, on the one hand, that it is possible to limit the lengths over which the fluid is circulated within them, and therefore limit the pressure drops of the fluid. This may make it possible to install all-series thermo-hydraulic networks in the evaporation zone and in the condensation zone or at the very least to limit the number of fluid branches in parallel in the said heat-exchange zones.

[0011] In a preferred alternative form, at least one panel which is a somewhat poor conductor of heat in the transverse direction perpendicular to its plane, comprises, on the face internal to the craft, at least one heat-exchange part of the evaporation zone and, on the face external to the craft, at least one heat-exchange part of the condensation zone. The said structural panel generally faces into space and is chosen so that, through its sizing, it obeys the other environmental constraints imposed by the mission. Thus, certain heat-exchange elements of the evaporation zone may be created at one of these panels, on the interior face, or outside the panel, while certain heat-exchange elements of the condensation zone are created opposite in this same panel, to transmit the heat to its exterior face thus able, if need be, to radiate at a higher temperature than that of the heat-exchange elements of the evaporation zone. In the case of a radiating panel at a high temperature in relation to the equipment operating temperature, the structural panels of the satellite can therefore be kept as radiating panels, thus reducing the overall mass balance of the thermal management system by comparison with a solution involving other fixed or deployable structures intended solely for radiating the thermal energy at high temperature.

[0012] According to an alternative form, at least one heat-exchange part of the evaporation zone is assembled with heat-transfer means in contact on one side with the compact heat-exchange elements and on another side with the dissipative equipment. The heat-transfer means partially cover a surface by means of several elements arranged on the said surface. These heat-transfer means may be heat pipes and/or fluid loops.

[0013] This configuration makes it possible to limit the overall surface area of the evaporation zone, broken down into as many elements as required by the layout of the heat pipes and of the dissipative equipment, which elements are connected together by simple tubes. Such exchangers allow for effective heat exchange. Further, their compactness makes it possible on the one hand to limit the lengths over which fluid is circulated within them, and therefore to limit the pressure drops of the fluid, and on the other hand makes it possible to limit the areas of heat-exchange elements exposed to the radiative surfaces, which elements are connected together by simple tubes. Such exchangers allow for effective heat exchange. Further, their compactness makes it possible to limit the lengths over which fluid is circulated within them, and therefore to limit the pressure drops of the fluid, and on the other hand makes it possible to limit the areas of heat-exchange elements exposed to space and therefore exposed to micrometeorite activity. The probability of impact is therefore limited. This reduces the mass of the additional thickness required for the heat-exchange elements facing out into space and therefore limits the mass of the thermal management system. The layout of such locally-arranged compact condensers may allow the thermo-hydraulic network to be installed in an all-series configuration or at the very least will make it possible to limit the number of fluid branches in parallel in the condensation zone.

[0014] According to an alternative form, at least one heat-exchange part of the condensation zone is assembled with heat-transfer means in contact on one side with the compact heat-exchange elements and on another side with a radiator. Likewise, the heat-transfer means partially cover a surface by means of several elements arranged on the said surface. These heat-transfer means may be heat pipes and/or fluid loops.

[0015] This configuration makes it possible to limit the overall surface area of the condensation zone, broken down into as many elements as required by the layout of the heat pipes and of the radiative surfaces, which elements are connected together by simple tubes. Such exchangers allow for effective heat exchange. Further, their compactness makes it possible to limit the lengths over which fluid is circulated within them, and therefore to limit the pressure drops of the fluid, and on the other hand makes it possible to limit the areas of heat-exchange elements exposed to space and therefore exposed to micrometeorite activity. The probability of impact is therefore limited. This reduces the mass of the additional thickness required for the heat-exchange elements facing out into space and therefore limits the mass of the thermal management system. The layout of such locally-arranged compact condensers may allow the thermo-hydraulic network to be installed in an all-series configuration or at the very least will make it possible to limit the number of fluid branches in parallel in the condensation zone.

[0016] According to an alternative form of the invention, the means of circulating the fluid in the various heat-exchange parts of the evaporation zone have a series and/or parallel configuration. An all-series configuration is preferable because it limits the thermo-hydraulic instabilities between the various heat-exchange parts. However, such a configuration is not always feasible from the point of view of admissible pressure drops. In the parallel configuration, it is possible to use elements to isolate branches so that in the event of a fault, one heat-exchange part can be isolated from the remainder of the system so that it will always be possible to perform the mission in a downgraded mode. This configuration may make it possible to dispense with the need for redundancy in the evaporation zone and, in general, in the thermal management device, thus affording a considerable weight saving.

[0017] According to an alternative form of the invention, the means of circulating the fluid in the various thermal fluid circulation circuits of the condensation zone have a series and/or parallel configuration. In the parallel configuration it is possible to use isolating elements so that if a thermal fluid circulation circuit is lost, isolating it from the remainder of the thermal system allows the mission to be performed in a downgraded mode. This layout may make it possible to dispense with the need for redundancy in the condensation zone and, in general, in the thermal management device, thus affording a considerable weight saving.

[0018] According to an alternative form of the invention, the thermal fluid circulation means comprise a first and a second circulation circuit, the heat-transfer means assembled with a heat-exchange part of the condensation zone having contact with at least a first and a second compact heat-exchange element, the first element being in contact with the first thermal fluid circulation circuit and the second element being in contact with the second circulation circuit.

[0019] According to an alternative form of the invention, the thermal fluid circulation means comprise a first and a second circulation circuit, the heat-transfer means assembled with a heat-exchange part of the evaporation zone having contact with at least a first and a second compact heat-exchange element, the first element being in contact with the
first thermal fluid circulation circuit and the second element being in contact with the second circulation circuit.

According to an alternative form of the invention, the evaporation zone comprises heat-exchange elements of the tubular pipe type which are the actual thermal fluid circulation means configured in series and/or in parallel and connected directly to dissipative equipment.

According to an alternative form of the invention, the condensation zone comprises heat-exchange elements of the tubular pipe type which are the actual thermal fluid circulation means configured in series and/or in parallel and connected directly to a radiative panel.

According to an alternative form, the evaporation zone and/or the condensation zone consists of a plurality of heat-exchange parts and the thermal fluid circulation means connect the said equipment in series and/or in parallel.

According to an alternative form of the heat engine type, the thermal fluid circulation loop also comprises an expansion zone directly upstream of the evaporation zone and a compression zone directly downstream of the evaporation zone. According to one embodiment of this last alternative form, the thermal fluid circulation means comprise means for reversing the direction in which the thermal fluid circulates so that the condensation zone and the evaporation zone are reversed. According to any embodiment of the last two alternative forms, the expansion zone comprises a plurality of pressure reducers to provide temperature control of the expansion zone. The device of the invention, through the use of the heat exchanger, proposes, in this alternative form, to collect all or some of the heat dissipated via satellite in a so-called evaporation zone associated with the structural panels (main walls of the satellite and internal racks), to compress the resultant steam leaving this zone and thus raise the temperature of the fluid before condensing it at the fixed or deployable radiators which will effectively, at high temperature and by radiation, remove all of the energy to cold space. The option of using thermally efficient compact elements in the evaporation zone and the condensation zone means that the levels of compression required in order to radiate at high temperature are minimized, and this has an appreciable impact on the energy consumption of the thermal management device, again manifesting itself in weight saving.

According to one alternative form of the invention, the solutions proposed hereinabove, apart from the heat engine alternative forms, apply to any diphasic loop in which the means of circulating the fluid is a mechanical pump, the loop having an evaporation zone and a condensation zone.

According to one alternative form of the invention, the solutions proposed hereinabove, apart from the heat engine alternative forms, apply to any diphasic loop in which the means of circulating the fluid is a capillary pump, the loop having an evaporation zone and a condensation zone.

The invention is particularly intended for telecommunications satellites. Advantageously, it comprises heat-exchange parts in contact with the said staged dissipative equipment. A satellite comprises a service module and a communications module and advantageously the external surfaces of the structural panels of the modules support at least one radiator. In an alternative form, at least one radiator of the satellite is deployable.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The invention will be better understood and other advantages will become apparent from reading the description which will follow, which is given without implying any limitation and by studying the attached figures among which:

**FIG. 1** depicts a functional diagram of the hydraulic architecture of a device to which the invention applies. It depicts an architecture comprising an evaporation zone, a condensation zone, and a means of circulating the heat-transfer or coolant fluid.

**FIG. 2** depicts a heat-exchange part of the evaporation zone intended to be used in a device according to the invention.

**FIG. 3** depicts a heat-exchange part of the condensation zone intended to be used in a device according to the invention.

**FIG. 4** depicts a diagram of a plurality of heat-exchange elements configured in parallel and in series in a device according to the invention for an evaporation zone or condensation zone.

**FIG. 5** depicts a hydraulic architecture of the thermal management device in a reverse circulation mode. The thermal fluid is circulated by means of a compression system.

**FIG. 6** depicts a hydraulic architecture of the thermal management device in which the thermal fluid is circulated using a mechanical pump.

**FIG. 7** depicts a hydraulic architecture of the thermal management device in which the thermal fluid is circulated by a capillary pump.

**FIG. 8** depicts a hydraulic architecture of the thermal management device in which the thermal fluid is circulated using a compressor. It depicts two modes of fluid circulation of the thermal fluid which are the reverse of one another according to the mode of operation of the device according to the invention.

**FIG. 9** depicts a satellite structural panel comprising, on the internal face, dissipative equipment in contact with part of the evaporation zone and, on the external face, a part of the condensation zone in contact with the radiative surface.

**DETAILED DESCRIPTION OF PREFERRED EMBODIMENT**

**FIG. 10** depicts a functional diagram of one embodiment of a hydraulic architecture of the device to which the invention applies. The thermal management device is made up of an evaporation zone, of a condensation zone, of a zone for circulating the heat-transfer or coolant fluid. The invention relates in particular to the evaporation Z1 and condensation Z3 zones of the thermal management device.

**FIG. 11** illustrates an evaporation zone associated with a part of a structural panel on which dissipative equipment is mounted. This evaporation zone is made up of two thermal fluid circulation circuits 11 and 12 in a series and/or parallel configuration not specified in this illustration. Each thermal fluid circulation circuit 11 and 12 of a heat-exchange part of the evaporation zone is made up of a plurality of heat-exchange elements 21 and 22 of compact type combined in series in this illustration by connecting tubes (the elements are not necessarily laid out in straight lines). The heat-exchange elements may be combined entirely in series as indicated in **FIG. 2**, but also in series/parallel in order to limit pressure drops and minimize mass. The thermal fluid circulation circuits are connected in this illustration by thermal means of the heat pipe type 310 and 311 to the equipment distributed over a surface 40.

**FIG. 3** shows a heat pipe tubes 310 and 311 are preferably straight tubes but may be elbowed for integration consider-
ations; they may either be incorporated into the panel or be mounted on the internal face on which the equipment is to be mounted. The distribution of heat pipes over the panel 40 is dependent on integration and mass considerations. The compact heat-exchange elements 21 and 22 are compact evaporators with high thermal energy transfer properties, high coefficients of evaporation and low pressure drops. These compact evaporators are generally parallelepipedal units with side lengths ranging from a few centimeters to a few tens of centimeters thus allowing the equipment to be mounted directly on top of them if necessary. The use of a network of heat pipes is not compulsory and the evaporation zone may be confined to thermal fluid circulation circuits of the tubular pipe type with performance optimized in terms of evaporation exchange coefficient, flux density and pressure drop. In such cases, the thermal fluid circulation circuits of the tubular pipe type are in direct contact with the dissipative equipment, the number of passes the equipment will be defined as a function of the permissible thermal gradient between the fluid and the equipment and by the temperatures that are to be guaranteed. The tubes may be arranged in series and in parallel to suit.

[0040] FIG. 3 illustrates a condensation zone associated with a part of a radiating panel 50 radiating towards cold space. This condensation zone is made up of two thermal fluid circulation circuits 11 and 12 in a series and/or parallel configuration not specified in this illustration. Each thermal fluid circulation circuit of a heat-exchange part of the condensation zone 11 and 12 is made up of a plurality of heat-exchange elements 61 and 62 of compact type combined in series in this illustration by connecting tubes (the elements are not necessarily laid out in straight lines). The heat-exchange elements may be combined entirely in series as indicated in FIG. 3, but also in series/parallel in order to limit pressure drops and minimize mass. In addition, an isolating system allows one or more thermal fluid circulation circuits to be operated according to the amount of thermal energy that needs to be radiated into space or according to considerations associated with failures (loss of one exchanger through micrometeorite impact). The thermal fluid circulation circuits are connected in this illustration by thermal means of the heat pipe type 320 and 321 to the radiative panel 50.

[0041] The heat pipes 320 and 321 are preferably straight tubes but may be elbowed for integration considerations, they may either be incorporated into the panel, when use is being made of a structural panel, or mounted on a face in the case of an additional radiative surface. The compact heat-exchange elements 61 and 62 are compact condensers having high thermal energy transfer properties, high condensation coefficients and low pressure drops. These compact condensers are generally parallelepipedal units or cylinders that may enclose the heat pipes at their end.

[0042] The heat-exchange parts of the evaporation zone and of the condensation zone as described hereinabove may be used on at least three hydraulic architectures of thermal management device (FIGS. 6, 7 and 8).

[0043] FIG. 4 illustrates an architecture that can be applied to the evaporation and condensation zones. The n heat-exchange elements of each zone 200, 201 and 202 are combined in parallel in this figure in order to optimize the heating and mass budget. The various zones 200, 201 and 202 are combined in series (200 and 201) and in parallel 202. This architecture allows control over the heat-exchange elements of the evaporation zone and therefore over the dissipative equipment at various temperature levels. This architecture allows the condensation zones to be balanced in order to even out the energy that is to be removed by each panel to suit the radiative environments. In an evaporation configuration, FIG. 4 depicts a diagram of an evaporation zone split into three heat-exchange parts, each made up of n heat-exchange elements (n may be different for each exchanger). The heat-exchange parts corresponding to the zones 201 and 202 are positioned in series and are therefore controlled to an identical temperature level, the zone 202 in parallel may be controlled to a different temperature level.

[0044] The heat-exchange elements have been laid out in a parallel/series configuration (via fluid lines 11 and 12 here proposed by way of example to run in parallel) which may differ from the configuration proposed in the figure.

[0045] FIG. 5 illustrates a reversible architecture that allows the direction of circulation of thermal fluid to be reversed so that the condensation zone and the evaporation zone become interchanged. This embodiment has the advantage that it reduces the heating budget that the system requires. The thermal energy Q absorbed at the radiative surfaces of zone Z3 (IR flux, solar flux, etc.) can thus be used to keep the dissipative equipment in contact with the zone Z1 at acceptable temperature levels in transfer phases and also in orbit. An isolating system allows the direction of circulation of the loop to be reversed. This reversible architecture is particularly intended for the architecture described in FIG. 8.

[0046] FIG. 6 illustrates an embodiment of thermal management device. This architecture comprises, connected in succession in a closed thermal fluid circulation loop, an evaporation zone Z1, a condensation zone Z3, a means of controlling the temperature of the loop, commonly known as a thermo-hydraulic reservoir, and a means of circulating the heat transfer fluid using a mechanical pump. The circulation circuits 401 of the evaporation zone Z1, of the condensation zone Z3 and between these two zones are preferably circuits for the diphasic circulation of the thermal fluid. The circulation circuits 402 between the condensation zone and the evaporation zone are preferably monophasic circulation circuits.

[0047] FIG. 7 illustrates another embodiment of a thermal management device. This architecture comprises, connected in succession in series in a closed thermal fluid circulation loop, an evaporation zone Z1 and a condensation zone Z3. The fluid is circulated by means of a capillary pump in the evaporation zone. The circulation circuits 501 of the evaporation zone, of the condensation zone and between these two zones are preferably circuits for the diphasic circulation of the thermal fluid. This architecture allows a greater quantity of heat to be collected on the surfaces covering the dissipative equipment and also allows a large amount of thermal energy to be radiated at the radiative surfaces. The circulation circuits 502 between the condensation zone and the evaporation zone are preferably monophasic circulation circuits.

[0048] FIG. 8 illustrates another embodiment of a thermal management device. This architecture comprises, connected in succession in series in a closed thermal fluid circulation loop, an evaporation zone Z1, a compression zone Z2, a condensation zone Z3 and an expansion zone Z4. Two modes of circulating the thermal fluid are depicted. A first mode, in which the circulation of the fluid is depicted in solid line, describes the architecture of the heat engine that allows the thermal energy Q to be removed, as a solid arrow in solid line, from the dissipative equipment into space. The zone Z1 is the
The evaporation zone and the zone Z3 is the condensation zone. The second mode, in which the circulation of the fluid is depicted in dotted line, describes the architecture of the heat engine in reverse circulation, as described by FIG. 5 herein-above. The thermal energy Q absorbed, in a solid arrow drawn in dotted line, at the radiative surfaces of zone Z3 (IR flux, solar flux, etc.) can thus be used to keep the dissipative equipment in contact with the zone Z1 at acceptable temperature levels during transfer phases and also in orbit. The expansion zone comprises one or more pressure reducers in series and/or in parallel to control parts of the evaporation zone at different temperature levels. For example, the number of pressure reducers used may be dependent on the number of branches of evaporator parts in parallel and on the associated temperature ranges. For example, pressure reducers of the capillary or thermostatic type may be used. The compression zone comprises one or more compressors. The thermal fluid used for this hydraulic architecture is rather of the coolant type.

FIG. 9 depicts a cross-sectional diagram of a satellite depicting part of the structure of a satellite 78 with one of the structural panels 74 comprising, on the internal surface, apart 751 of the evaporation zone in contact with dissipative electronic equipment 761 and 762 supported by the panel 74, which is a poor conductor perpendicular to its plane, and on the external surface a part 73 of the condensation zone in contact with a part of the radiative surface 72. The structural panel 74 is, for example, the north-facing panel of a telecommunications satellite. A telecommunications satellite is usually made up of panels commonly known as north, south, east, west, earth and anti-earth. All these panels may have an internal face with part of the evaporation zone and an external face with part of the condensation zone like the panel 74 depicted in FIG. 8. In addition, the satellite comprises, inside the casing 78, electronic equipment 763 and 764 arranged in racks and decoupled from the panels of the satellite. Parts of the evaporation zone 752 and 753 have the function of collecting the thermal energy generated by the dissipative equipment. The radiative surface is directed into space. The radiative surface is covered with several protective layers 71. The layers improve protection against micrometeorite attack but do not prevent conductive heat transfer between the condensation zone and the radiation zone. The layer 70 covering the radiative surfaces is a means of emitting the dissipated energy while at the same time limiting the absorption of external thermal flux (solar flux and the like). It may be made up of mirrors. The thermal fluid circulation means 79 circulate within the parts 751, 752 and 753 of the evaporation and condensation zones made up of one or more heat-exchange parts. The dissipative equipment positioned in racks inside the satellite and the dissipative equipment positioned on the structural panels is associated with one and the same thermal fluid hydraulic circuit by means of circuit branches in parallel and/or series.

A telecommunications satellite comprises a module known as the service module and a communication module. The panels of these two modules may be arranged with the thermal management device with part of the evaporation zone on the internal face and part of the condensation zone on the external face. The thermal gradient between the faces of the panels is high while the thermal gradient longitudinally along the face of the panels is practically zero.

One advantage of the device according to the invention is the use of a thermal energy transfer architecture in which the evaporation zone is thermally decoupled from the condensation zone, these zones being structurally connected to the same panels.

What is claimed is:

1. Thermal management device intended to collect the heat dissipated by a group of dissipative equipment of a spacecraft in an evaporation zone before discharging this heat to cold space via a condensation zone, spacecraft comprising a plurality of structural panels and the thermal management device comprising means of circulating thermal fluid connecting, in a closed loop, at least the evaporation zone and the condensation zone, the evaporation zone constituting a first heat-exchange surface for exchanging heat, directly or indirectly via other heat-transfer means, with the dissipative equipment, and the condensation zone constituting a second heat-exchange surface for exchanging heat, directly or indirectly via other heat-transfer means, with radiators radiating into space, wherein the evaporation zone and/or the condensation zone consists of at least one heat-exchange part comprising a network of a plurality of compact heat-exchange elements distributed over their respective heat-exchange surface and connected in series and/or in parallel by the tubes of the thermal fluid circulation means.

2. Thermal management device according to claim 1, wherein at least one panel which is a somewhat poor conductor of heat in the transverse direction perpendicular to its plane, comprises, on the face internal to the craft, at least one heat-exchange part of the evaporation zone and, on the face external to the craft, at least one heat-exchange part of the condensation zone.

3. Thermal management device according to claim 1, comprising at least a heat-exchange part of the evaporation zone is assembled with heat-transfer means in contact on one side with the compact heat-exchange elements and on another side with the dissipative equipment.

4. Thermal management device according to claim 1, comprising at least a heat-exchange part of the condensation zone is assembled with heat-transfer means in contact on one side with the compact heat-exchange elements and on another side with a radiator.

5. Thermal management device according to claim 1, wherein the thermal fluid circulation means comprise a first and a second circulation circuit, the heat-transfer means assembled with a heat-exchange part of the evaporation zone having contact with at least a first and a second compact heat-exchange element, the first element being in contact with the first thermal fluid circulation circuit and the second element being in contact with the second circulation circuit.

6. Thermal management device according to claim 1, wherein the thermal fluid circulation means comprise a first and a second circulation circuit, the heat-transfer means assembled with a heat-exchange part of the condensation zone having contact with at least a first and a second compact heat-exchange element, the first element being in contact with the first thermal fluid circulation circuit and the second element being in contact with the second circulation circuit.

7. Thermal management device according to claim 1, wherein the evaporation zone and/or the condensation zone consists of a plurality of heat-exchange parts and the thermal fluid circulation means connect the said equipment in series and/or in parallel.

8. Thermal management device according to claim 1, wherein the thermal fluid circulation loop also comprises an
expansion zone directly upstream of the evaporation zone and a compression zone directly downstream of the evaporation zone.

9. Thermal management device according to claim 8, wherein the thermal fluid circulation means comprise means for reversing the direction in which the thermal fluid circulates so that the condensation zone and the evaporation zone are interchanged.

10. Thermal management device according to claim 8, wherein the expansion zone comprises a plurality of pressure reducers to provide temperature control for a plurality of heat-exchange parts of the evaporation zone at one or more different temperature levels, the thermal fluid circulation means connecting the said equipment in parallel.

11. Thermal management device according to claim 1, wherein the means for circulating the thermal fluid is a mechanical pump.

12. Thermal management device according to claim 1, wherein the means for circulating the thermal fluid is a capillary pump.

13. Thermal management device according to claim 1, wherein the condensation zone also comprises heat-exchange means of the tubular pipe type which are the thermal fluid circulation means configured in series and/or in parallel and connected directly to a radiating panel.

14. Thermal management device according to claim 1, wherein the condensation zone also comprises heat-exchange means of the tubular pipe type which are the thermal fluid circulation means configured in series and/or in parallel and connected directly to dissipative equipment.

15. Telecommunications satellite, comprising a thermal management device according to claim 1.

16. Satellite according to claim 15, comprising a service module and a communications module, wherein the external surfaces of the structural panels of the modules support at least one radiator.

17. Satellite according to claim 15, wherein at least one radiator is deployable.