(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 June 2017 (29.06.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/108486 A1

(51) International Patent Classification:
F28F 3/12 (2006.01) *F28D 9/00* (2006.01)
F01P 11/08 (2006.01) *F28D 15/00* (2006.01)
F01M 5/00 (2006.01) *F28D 20/02* (2006.01)
F01M 11/00 (2006.01)

(21) International Application Number:
PCT/EP2016/080690

(22) International Filing Date:
12 December 2016 (12.12.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1522629.3 22 December 2015 (22.12.2015) GB

(71) Applicant: **JAGUAR LAND ROVER LIMITED** [GB/GB]; Abbey Road, Whitley, Coventry Warwickshire CV3 4LF (GB).

(72) Inventors: **OWENS, Adam**; c/o Jaguar Land Rover, Patents Department W/1/073, Abbey Road, Whitley, Coventry Warwickshire CV3 4LF (GB). **HUTCHINS, William**; c/o Jaguar Land Rover, Patents Department W/1/073, Abbey Road, Whitley, Coventry Warwickshire CV3 4LF (GB).

(74) Agent: **BORTON, Claire**; c/o Jaguar Land Rover, Patents Department W/1/073, Abbey Road, Whitley, Coventry Warwickshire CV3 4LF (GB).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) Title: HEAT TRANSFER APPARATUS

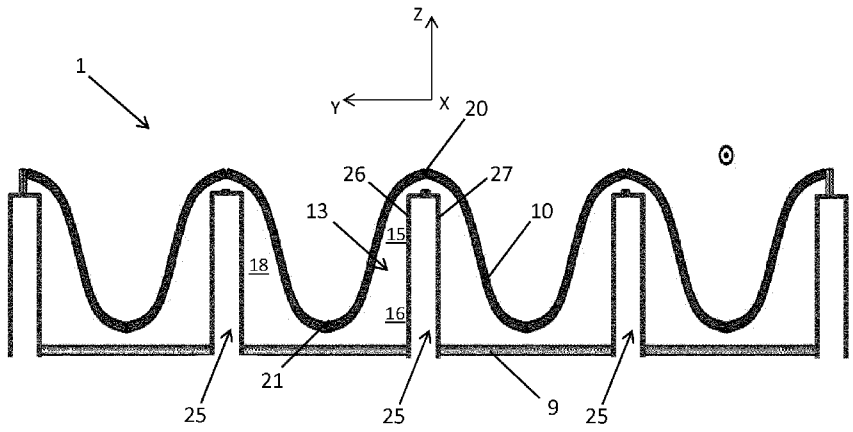


FIG. 8

(57) Abstract: The present disclosure relates to a heat transfer apparatus (1) for a housing (6), such as a transmission housing (6). The heat transfer apparatus (1) has an internal wall (10) for contacting a liquid in the housing; and an external wall (9) for contacting a cooling fluid. One or more heat transfer chamber (13) is disposed between the internal wall (10) and the external wall (9). A heat transfer medium (18) is disposed in each heat transfer chamber (13). Cooling means is provided for cooling the heat transfer medium (18); and heating means is provided for heating the heat transfer medium (18). The cooling means is disposed above the heating means. The present disclosure also relates to a housing (6) having one or more heat transfer apparatus (1); and to a vehicle (2) having one or more heat transfer apparatus (1).

WO 2017/108486 A1

HEAT TRANSFER APPARATUS

TECHNICAL FIELD

The present disclosure relates to heat transfer apparatus. More particularly, but not exclusively, the present disclosure relates to a heat transfer apparatus; to a housing comprising one or more heat transfer apparatus; and to a vehicle comprising one or more heat transfer apparatus.

BACKGROUND

Transmission and driveline elements which are not coupled to an external thermal management system (to provide or reject thermal energy to regulate temperature) may suffer from degraded efficiency during warm-up on a drive cycle, due to lubricants being at sub-optimal temperatures. To accelerate warm-up, an active heater and/or insulation can be applied. An active heater requires external energy input, reducing efficiency, and has a high degree of redundancy (as a non-functional mass in vehicle). Conversely, insulation can accelerate warm-up, but may require cooling to prevent over-heating when warm-up is completed. High-intensity drive events may place extreme thermal loads on drivetrain components. To accommodate these events typically requires an oversized cooling system (for example an air duct, oil cooler etc.).

At least in certain embodiments, the present invention provides a heat transfer apparatus for overcoming or ameliorating at least some of the problems associated with prior art systems.

SUMMARY OF THE INVENTION

Aspects of the present invention relate to a heat transfer apparatus; to a housing comprising one or more heat transfer apparatus; and to a vehicle comprising one or more heat transfer apparatus.

According to a further aspect of the present invention there is provided heat transfer apparatus for a housing, the heat transfer apparatus comprising:

an internal wall for contacting a liquid in the housing;

an external wall for contacting a cooling fluid;

one or more heat transfer chamber disposed between said internal wall and said external wall;

a heat transfer medium being disposed in each heat transfer chamber;

cooling means for cooling the heat transfer medium; and

heating means for heating the heat transfer medium;

wherein the cooling means is disposed above the heating means. The cooling means and the heating means are configured to promote convection circulation of the heat transfer medium in the one or more heat transfer chamber. The cooling means and the heating means may be arranged to establish a thermal inversion of the heat transfer medium within the one or more heat transfer chamber. In use, the heat transfer medium circulates within the one or more heat transfer chamber, thereby promoting the transfer of heat from the liquid in the housing to the cooling fluid. The liquid may be a lubricant in the housing. The heat transfer medium typically begins to circulate once a suitable operating temperature has been reached. The transmission of heat energy from the liquid in the housing may be reduced below this temperature. Thus, the efficiency of the heat transfer medium in transmitting heat energy may be reduced at low temperatures, for example during warm-up in a drive cycle of an internal combustion engine, which may expedite heating of the liquid in the housing. At least in certain embodiments this may be advantageous to expedite heating of a liquid, such as a lubricant, in the housing to an operating temperature.

The cooling means may be suitable for cooling the heat transfer medium in an upper portion of each heat transfer chamber; and the heating means may be suitable for heating the heat transfer medium in a lower portion of each heat transfer chamber. At least in certain embodiments the heat transfer medium may circulate between said upper and lower portions of the chamber.

The cooling means may comprise a cooling member. The cooling member may be connected to the external wall. The cooling member may extend vertically upwardly from the external wall. A cooling fin may be formed on the external wall proximal to the connection between the cooling member and the external wall. The cooling fin may extend into the cooling fluid to promote cooling of the cooling member. The cooling fin may extend vertically downwardly from the external wall.

The cooling means may be suitable for conveying the cooling fluid into the upper portion of each heat transfer chamber. The cooling means may comprise one or more cooling slot formed in the external wall. The cooling slot may extend upwardly into each heat transfer chamber. In particular, the cooling slot may extend into the upper portion of each heat transfer chamber. In alternate arrangements, the cooling means may, for example, comprise a cavity, aperture, recess, groove or channel formed in the external wall. The cooling fluid may perform cooling of the heat transfer medium in the upper portion of the chamber. This arrangement may have particular application in a protected environment. Alternatively, the cooling means may comprise a conduit extending through the upper portion of each heat

transfer chamber for conveying cooling fluid. The conduit may, for example, be open to allow the flow of the cooling fluid.

The heat transfer apparatus comprises heating means. The heating means may be configured to heat the heat transfer medium in the lower portion of each heat transfer chamber. The heating means may comprise a section of the internal wall disposed adjacent to each heat transfer chamber. The heating means may be configured to promote convection circulation of the heat transfer medium in the one or more heat transfer chamber. The heating means may help to establish a thermal inversion of the heat transfer medium within the one or more heat transfer chamber. The heating means may be disposed in the lower portion of each heat transfer chamber. The heating means may comprise a section of the internal wall disposed adjacent to the lower portion of each heat transfer chamber. The internal wall may extend downwardly to promote heating of the heat transfer medium in the lower portion of the one or more heat transfer chamber. The heating means may comprise at least one trough formed in the internal wall. The internal wall may have a corrugated profile. The profile and/or geometry of the corrugations may be optimised, for example depending on an available package envelope. The rate of convection circulation of the heat transfer medium will be a function of corrugation angle and/or scale. The internal wall may, for example, comprise at least one peak and at least one trough. The internal wall may have a polygonal profile or a curved profile. For example, the internal wall may have a sinusoidal wave profile, a triangular wave profile, a square-wave profile or a saw-tooth profile. Other profiles are also envisaged. The internal wall may comprise a concave section which forms an undercut to the profile of each heat transfer chamber. In alternate arrangements, the heating means may comprise a heating member extending from said internal wall. The heating means may comprise one or more heating plate extending downwardly from the internal wall into each heat transfer chamber.

Liquid retention means may be disposed in the at least one trough. The liquid retention means may retain the liquid in the at least one trough. The liquid retention means may comprise a metallic foam. The metallic foam may have a porous structure. The metallic foam may be thermally conductive, thereby promoting cooling of the liquid.

A heat conducting matrix may be disposed within each heat transfer chamber. The heat conducting matrix may comprise a metallic foam. The metallic foam may have a porous structure. The metallic foam may be thermally conductive. The metallic foam enables a high heat transfer rate into the heat transfer medium.

The heat transfer medium may be a solid at low temperatures and may change to a liquid above a melting temperature. The heat transfer apparatus may provide relatively low thermal resistance at temperatures higher than the melting temperature; and relatively high thermal resistance at temperatures lower than the melting temperature of the heat transfer medium. Alternatively, the heat transfer medium may remain in a liquid state within a normal operating temperature range.

The heat transfer medium may comprise a phase-change material which, in use, changes phase from a solid to a liquid. The phase-change material may have a phase change temperature in the range 80-120°C or 90-110°C. More particularly, the phase-change material may have a phase change temperature of approximately 90°C or approximately 100°C. The phase-change material may comprise a lipid-based material or a molten salt. The phase-change material may be wax, such as paraffin wax, or a molten salt. The wax may have a melting temperature of approximately 90°C. The composition of the phase-change material may be refined to adjust the phase change temperature (i.e. melting point) and/or adsorption energy of the phase-change material. The heat transfer medium may have a high heat of fusion and may absorb thermal energy as it changes from the solid state to the liquid state. In steady-state, medium load conditions, this spike of energy absorption will create a dynamic imbalance, as the warm-up rate of the liquid will decay, then increase once more when the phase-change material is a liquid, until steady-state is reached. The phase-change material may be optimised for an 80-90% load case, for each a high intensity, short duration events. The temperature may not reach steady-state under such events, but it could remain within an acceptable limit, without having to over-specify the cooling capacity, which would add mass.

The external wall may be disposed below the internal wall. The heat transfer apparatus may be disposed at the bottom of the housing.

According to a further aspect of the present invention there is provided a housing comprising one or more heat transfer apparatus as described herein. The housing may be a transmission housing.

According to a further aspect of the present invention there is provided a vehicle comprising one or more heat transfer apparatus as described herein.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims

and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the present invention will now be described, by way of example only, with reference to the accompanying figures, in which:

Figure 1 shows a schematic representation of a vehicle incorporating a heat transfer apparatus in accordance with an embodiment of the present invention;

Figure 2 shows a schematic section view of a transmission incorporating a heat transfer apparatus in accordance with an embodiment of the present invention;

Figure 3 shows an end view of the heat transfer apparatus shown in Figure 2;

Figure 4 shows a perspective view of the heat transfer apparatus shown in Figure 2;

Figure 5 illustrates the convection circulation of a heat transfer medium within the heat transfer chambers of the heat transfer apparatus shown in Figure 2;

Figure 6 shows a side elevation of a heat transfer apparatus in accordance with a further embodiment of the present invention;

Figure 7 shows a perspective view of the heat transfer apparatus shown in Figure 5;

Figure 8 shows an end view of a heat transfer apparatus in accordance with a further embodiment of the present invention; and

Figure 9 illustrates the convection circulation of a heat transfer medium within the heat transfer chambers of the heat transfer apparatus shown in Figure 8.

DETAILED DESCRIPTION

A heat transfer apparatus 1 in accordance with an embodiment of the present invention will now be described with reference to the accompanying figures.

A vehicle 2 incorporating an internal combustion engine 3 connected to a transmission 4 is shown schematically in Figure 1. The vehicle 2 has a longitudinal axis X, a transverse axis Y and a vertical axis Z (extending out of the plane in Figure 1). A transverse sectional view of the transmission is shown in Figure 2. The transmission 4 comprises a gear train 5 and a transmission housing 6. A lubricant 7, such as oil, is provided in the transmission housing 6 to lubricate the gear train 5. A lower section of the transmission housing 6 forms a sump 8

for collecting the lubricant 7. The heat transfer apparatus 1 is incorporated into an external wall 9 of the transmission 4 disposed at the bottom of the transmission housing 6. The external wall 9 is exposed to incident airflow under of the vehicle 2. When the vehicle 2 is in motion, the incident airflow transfers heat away from the transmission housing 6, thereby performing cooling.

With reference to Figure 3, the external wall 9 of the transmission housing 6 forms an external wall of the heat transfer apparatus 1. The heat transfer apparatus 1 comprises an internal wall 10, a plurality of external cooling fins 11, and an end wall 12. The external wall 9 and the internal wall 10 are formed from thermally conductive material, for example a metal alloy. The external wall 9, the internal wall 10, the cooling fins 11 and the end wall 12 may be formed in a single piece, for example as an extrusion or a casting. The external wall 9 and the internal wall 10 are spaced apart from each other to form a plurality of heat transfer chambers 13. The heat transfer chambers 13 are disposed between the external wall 9 and the internal wall 10. The heat transfer chambers 13 have an open configuration such that adjacent heat transfer chambers 13 remain in communication with each other. The heat transfer chambers 13 extend vertically upwardly and comprise an upper portion 15 and a lower portion 16. Cooling means in the form of a cooling plate 17 is associated with each of the heat transfer chambers 13. In the present embodiment the cooling plates 17 form a boundary between adjacent heat transfer chambers 13 in the heat transfer apparatus 1. The heat transfer chambers 13 are at least substantially filled with a heat transfer medium 18. The cooling plates 17 are configured to provide cooling at least in the upper portion 15 of the heat transfer chambers 13. Heating means are provided for heating the heat transfer medium 18 in each of the heat transfer chambers 13. In particular, the heating means is arranged to provide heating at least in the lower portion 16 of the heat transfer chambers. In the present embodiment the internal wall 10 is profiled to provide said heating means by conducting heat from the lubricant 7 into the heat transfer chamber 13. In use, convection circulation of the heat transfer medium 18 within each heat transfer chamber 13 promotes the transfer of heat between the internal wall 10 and the external wall 9 of the transmission housing 6. The cooling plates 17 promote convection circulation by cooling the heat transfer medium 18 in the upper portion 15 of the heat transfer chambers 13. The cooling plates 17 may be continuous or comprise one or more aperture to control cooling of the heat transfer medium 18 within the heat transfer chambers 13.

The heat transfer medium 18 in the present embodiment is a phase-change material (PCM) having a high heat of fusion. The heat transfer medium 18 is a solid at room temperature but undergoes a phase change to a liquid when heated. The heat transfer medium 18 absorbs

thermal energy as it changes from a solid to a liquid. A suitable phase-change material for the heat transfer apparatus 1 is a wax or a molten salt having a melting temperature of approximately 90°C. It is not essential that the heat transfer medium 18 is a phase-change material. The heat transfer medium 18 may be selected so as to remain in a liquid state during normal operation of the vehicle 2. For example, the heat transfer medium 18 may be oil.

A heat conducting matrix 19 is disposed within each of the heat transfer chambers 13. The heat conducting matrix 19 is formed of a thermally conductive material and promotes the conduction of heat into the heat transfer medium 18 within the heat transfer chambers 13. At least in certain embodiments, the heat conducting matrix 19 contacts the internal wall 10 to promote thermal conduction into the heat transfer chambers 13. In use, the heat conducting matrix 19 conducts heat into the heat transfer medium 18. The heat conducting matrix 19 has an open cell structure which allows movement of the heat transfer medium 18 within the heat transfer chambers 13 due to convection currents. The heat conducting matrix 19 in the present embodiment is a metallic foam. The metallic foam has a porous structure and the size of the pores may be selected to control the flow of the heat transfer medium 18 within the heat transfer chambers 13.

As shown in Figure 4, the heat transfer apparatus 1 extends in the longitudinal direction X of the vehicle 2 such that the heat transfer chambers 13 have a three-dimensional form. As shown in Figures 3 and 4, the internal wall 10 comprises alternating peaks 20 and troughs 21 in a transverse direction. The cooling fins 11 are substantially aligned with the peaks 20 and offset from the troughs 21. In the present embodiment the internal wall 10 has a sinusoidal section in said transverse direction. In alternate embodiments the internal wall 10 may have a square, a triangular or a saw-tooth section in the transverse direction. Other polygonal and curved sections are also envisaged. The layer of heat transfer medium 18 within the heat transfer chambers 13 is non-planar.

As shown in Figure 2, the lubricant 7 provided in the transmission housing 6 collects in the troughs 21. The troughs 21 thereby form galleries for the lubricant 7. The heat transfer medium 18 disposed in the lower portion 16 of each of the heat transfer chambers 13 is heated by the lubricant 7 collected in the troughs 21. Lubricant retention means 22 is disposed in each of the troughs 21 to reduce movement of the lubricant 7, for example due to acceleration of the vehicle 2 (in a vertical direction and/or a lateral direction and/or a longitudinal direction). The lubricant retention means 22 has an open cell structure which allows movement of the lubricant 7. In the present embodiment the lubricant retention means

22 is a metallic foam. The metallic foam has a porous structure and the size of the pores may be selected to control the flow of the lubricant 7 within the troughs 21.

The operation of the heat transfer apparatus 1 will now be described with particular reference to Figures 3 and 5. When the internal combustion engine 3 is first started the heat transfer medium 18 is typically at a temperature below its melting temperature and is in a solid state. The internal combustion engine 3 rotates the gear train 5, generating heat which is transmitted to the lubricant 7 through conduction. The lubricant 7 collects at the bottom of the transmission housing 6 in the troughs 21 formed by the internal wall 10. The lubricant retention means 22 helps to reduce the movement of the lubricant 7 within the troughs 21 due to acceleration of the vehicle 2. Heat energy is transmitted from the lubricant 7 into the internal wall 10 through conduction. The heat conducting matrix 19 is heated by conduction and the heat energy released into the heat transfer medium 18. The heat conducting matrix 19 promotes the conduction of heat energy into the heat transfer medium 18. The heat transfer medium 18 is heated progressively to its melting temperature. The heat transfer medium 18 is a phase-change material and absorbs heat energy as it undergoes a phase change from a solid to a liquid. The high heat of fusion of the heat transfer medium 18 provides additional cooling of the lubricant 7 at the melting temperature of the heat transfer medium 18. It will be appreciated that the composition of the heat transfer medium 18 may be configured to set the melting temperature at an appropriate operating temperature of the lubricant 7.

The heat transfer medium 18 is heated above its melting temperature and becomes a liquid. The heat transfer chambers 13 are configured to allow convention circulation of the heat transfer medium 18. The external wall 9 is cooled by the incident airflow beneath the vehicle 2. It will be appreciated that the cooling fins 11 promote cooling of the external wall 9. The cooling plates 17 are connected to the external wall 9 and heat energy is conducted from the heat transfer medium 18 to the external wall 9. The cooling plates 17 extend vertically upwardly into the heat transfer chambers 13 and are effective to perform cooling of the heat transfer medium 18 in the upper portion 15 of each heat transfer chamber 13. Thus, the cooling plates 17 function as cooling means for cooling the heat transfer medium 18 in the upper portion 15 of each heat transfer chamber 13. The internal wall 10 is heated by the lubricant 7 within the transmission housing 6. The troughs 21 extend downwardly below the peaks 20 and are effective to perform heating of the heat transfer medium 18 in the lower portion 16 of each heat transfer chamber 13. Thus, the troughs 21 functions as heating means for heating the heat transfer medium 18 in the lower portion 16 of each heat transfer chamber 13.

As illustrated in Figure 5, the localised cooling provided by the cooling plates 17 promotes downwards flow of the heat transfer medium 18. Moreover, the heating of the internal wall 10 by the lubricant 7 provides localised heating of the heat transfer medium 18. The opposing arrangement of the cooling plates 17 and the internal wall 10 help to establish convection circulation of the heat transfer medium 18 within the heat transfer chambers 13. The open cell structure of the heat conducting matrix 19 allows the movement of the heat transfer medium 18 within the heat transfer chambers 13 when in its liquid state. The circulation of the heat transfer medium 18 within adjacent heat transfer chambers 13 is illustrated by the arrows A in Figure 5. The circulation of the heat transfer medium 18 promotes the exchange of heat energy between the lubricant 7 and the external wall 9. In the illustrated arrangement, adjacent heat transfer chambers 13 are in communication with each other.

An alternative embodiment of the heat transfer apparatus 1 in accordance with a further embodiment of the present invention is shown in Figures 6 and 7. The heat transfer apparatus 1 is a modified arrangement of the previous embodiment. The description herein describes the differences over the previous embodiment. Like reference numerals are used for like components.

The internal wall 10 in this embodiment comprises a series of concave sections 23. The concave sections 23 form recesses on opposing sides of the trough 21. The concave sections 23 form a constriction 24 between the upper portion 15 and the lower portion 16 of each heat transfer chamber 13. The concave section 23 thereby forms an undercut for promoting heating of the heat transfer medium 18 by the lubricant 7. The operation of the heat transfer apparatus 1 in this embodiment is unchanged from the previous embodiment.

An alternative embodiment of the heat transfer apparatus 1 in accordance with a further embodiment of the present invention is shown in Figures 8 and 9. The heat transfer apparatus 1 is a modified arrangement of the previous embodiment. The description herein describes the differences over the previous embodiment. Like reference numerals are again used for like components.

With reference to Figure 8, the external wall 9 of the transmission housing 6 forms an external wall of the heat transfer apparatus 1. The heat transfer apparatus 1 comprises an external wall 9 and an internal wall 10. The external wall 9 and the internal wall 10 are spaced apart from each other to form a plurality of heat transfer chambers 13. The heat transfer chambers 13 are formed between the external wall 9 and the internal wall 10. The

heat transfer chambers 13 extend vertically and comprise an upper portion 15 and a lower portion 16. As in the previous embodiments, the heat transfer chambers 13 are at least substantially filled with a heat transfer medium 18. Cooling means in the form of a cooling slot 25 is associated with each of the heat transfer chambers 13. The cooling slots 25 are formed in the external wall 9 and extend vertically upwardly into the heat transfer chambers 13 formed between the external wall 9 and the internal wall 10. The cooling slots 25 are open to the incident airflow beneath the vehicle 2. The incident airflow provides a ram/fan effect which, in use, promotes cooling. Moreover, the cooling slots 25 enable the incident airflow to perform cooling of the heat transfer medium 18 in the upper portion 15 of each heat transfer chamber 13 to provide a downdraft. The cooling slots 25 have sidewalls 26, 27 which are also exposed to the incident airflow. To promote the incident airflow, the cooling slots 25 may extend substantially parallel to a longitudinal axis X of the vehicle 2. The internal wall 10 comprises alternating peaks 20 and troughs 21. The cooling slots 25 are substantially aligned with the peaks 20 and offset from the troughs 21. In the present embodiment the internal wall 10 has a sinusoidal section.

In use, heat energy is transmitted from the lubricant 7 into the internal wall 10 through conduction. The heat energy is released into the heat transfer medium 18. The troughs 21 formed in the internal wall 10 promote heating of the heat transfer medium 18 in the lower portion 16 of each heat transfer chamber 13. The troughs 21 thereby function as heating means for heating the heat transfer medium 18 in the lower portion 16 of each heat transfer chamber 13. Conversely, the cooling slots 25 function as cooling means for cooling the heat transfer medium 18 in the upper portion 15 of each heat transfer chamber 13. The resulting thermal inversion of the heat transfer medium 18 helps to establish a circulating flow within each heat transfer chamber 13. As illustrated schematically in Figure 9, the vertical portions of the internal wall 10 are heated by the lubricant 7, thereby promoting an upwards flow of the heat transfer medium 18 adjacent to the internal wall 10. Conversely, the sidewalls 26, 27 of the cooling slots 25 are cooled by the incident airflow, thereby promoting a downwards flow of the heat transfer medium 18 adjacent to the external wall 9. Thus, convection circulation of the heat transfer medium 18 is established within the heat transfer chambers 13 to promote the transfer of thermal energy from the lubricant 7 into the incident airflow. The circulation of the heat transfer medium 18 is illustrated by the arrows A in Figure 9.

It will be appreciated that various changes and modifications can be made to the heat transfer apparatus 1 described herein without departing from the scope of the present invention. Although the heat transfer apparatus 1 has been described with reference to a transmission 4, it will be appreciated that the invention is not limited to this application. For

example, the heat transfer apparatus 1 may be implemented in a sump for an internal combustion engine.

The heat transfer apparatus 1 comprises heating means for heating the heat transfer medium 18 in the lower portion 15 of each heat transfer chamber 13. The heating means is described herein as being provided by profiling the internal wall 10 so as to extend downwardly alongside the heat transfer chamber 13 such that, in use, thermal energy is introduced into the lower portion 16 of the heat transfer chamber 13. In alternate embodiments, the heating means may comprise a vertical slot or channel formed in the internal wall 10 and extending downwardly. In a further alternative, the heating means may comprise one or more heating member projecting downwardly from the internal wall 10. The one or more heating member may comprise a heating plate mounted to the internal wall 10. In use, the heating member may be heated by the lubricant 7 through conduction. The heating member may extend vertically downwardly into the region between said external wall 9 and said internal wall 10. In certain embodiments, the heat transfer chambers 13 may be formed by alternating heating and cooling plates extending from the internal wall 10 and the external wall 9 respectively.

The one or more heating member may be used in conjunction with the sinusoidal internal wall 10 described herein. Alternatively, the one or more heating member may be used instead of the sinusoidal internal wall 10. For example, the internal wall 10 may be substantially planar and the one or more heating member configured to extend downwardly from said internal wall 10.

The heat transfer chambers 13 in the embodiments described herein have had an open configuration which allows the communication of the heat transfer medium 18 between adjacent heat transfer chambers 13. In certain embodiments, the heat transfer chambers 13 may have a closed configuration.

CLAIMS:

1. Heat transfer apparatus for a housing, the heat transfer apparatus comprising:
an internal wall for contacting a liquid in the housing;
an external wall for contacting a cooling fluid;
one or more heat transfer chamber disposed between said internal wall and said external wall;
a heat transfer medium being disposed in each heat transfer chamber;
cooling means for cooling the heat transfer medium; and
heating means for heating the heat transfer medium;
wherein the cooling means is disposed above the heating means.

2. Heat transfer apparatus as claimed in claim 1, wherein the cooling means is suitable for cooling the heat transfer medium in an upper portion of each heat transfer chamber; and the heating means is suitable for heating the heat transfer medium in a lower portion of each heat transfer chamber.

3. Heat transfer apparatus as claimed in claim 1 or claim 2, wherein the cooling means comprises a cooling member.

4. Heat transfer apparatus as claimed in claim 3, wherein the cooling member is connected to the external wall.

5. Heat transfer apparatus as claimed in claim 4, wherein the cooling member extends vertically from the external wall.

6. Heat transfer apparatus as claimed in claim 4 or claim 5, wherein a cooling fin is formed on the external wall proximal to the connection between the cooling member and the external wall.

7. Heat transfer apparatus as claimed in claim 1 or claim 2, wherein the cooling means comprises a cooling slot formed in the external wall.

8. Heat transfer apparatus as claimed in any one of the preceding claims, wherein the heating means comprises a section of the internal wall disposed adjacent to each heat transfer chamber.

9. Heat transfer apparatus as claimed in claim 8, wherein the heating means comprises at least one trough formed in the internal wall.

10. Heat transfer apparatus as claimed in claim 9, wherein liquid retention means is disposed in the at least one trough.

11. Heat transfer apparatus as claimed in claim 10, wherein the liquid retention means comprises a metallic foam.

12. Heat transfer apparatus as claimed in any one of claims 1 to 7, wherein the heating means comprises a heating member extending from said internal wall.

13. Heat transfer apparatus as claimed in any one of the preceding claims, wherein a heat conducting matrix is disposed within each heat transfer chamber.

14. Heat transfer apparatus as claimed in claim 13, wherein the heat conducting matrix comprises a metallic foam.

15. Heat transfer apparatus as claimed in any one of the preceding claims, wherein the heat transfer medium comprises a phase-change material.

16. Heat transfer apparatus as claimed in any one of the preceding claims, wherein the external wall is disposed below the internal wall.

17. A housing comprising one or more heat transfer apparatus as claimed in any one of the preceding claims.

18. A housing as claimed in claim 17, wherein the housing is a transmission housing.

19. A vehicle comprising one or more heat transfer apparatus as claimed in any one of claims 1 to 16.

20. Heat transfer apparatus substantially as herein described with reference to the accompanying figures.

21. A vehicle substantially as herein described with reference to the accompanying figures.

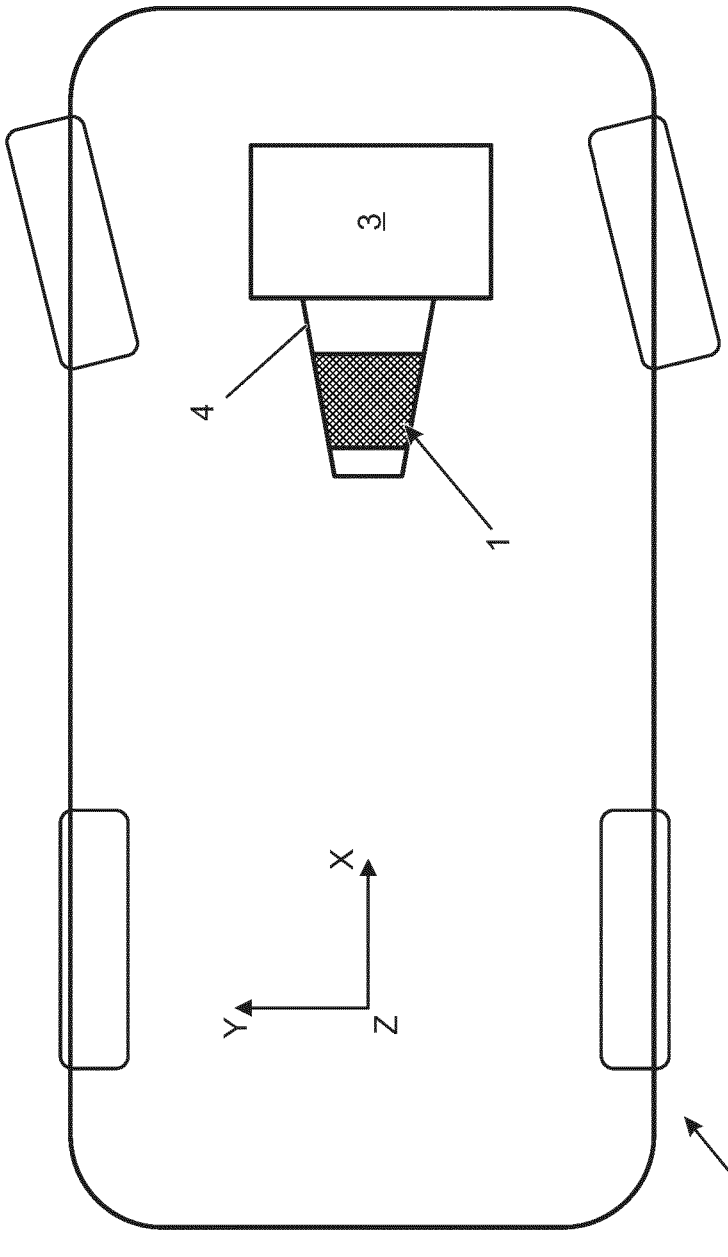


FIG. 1

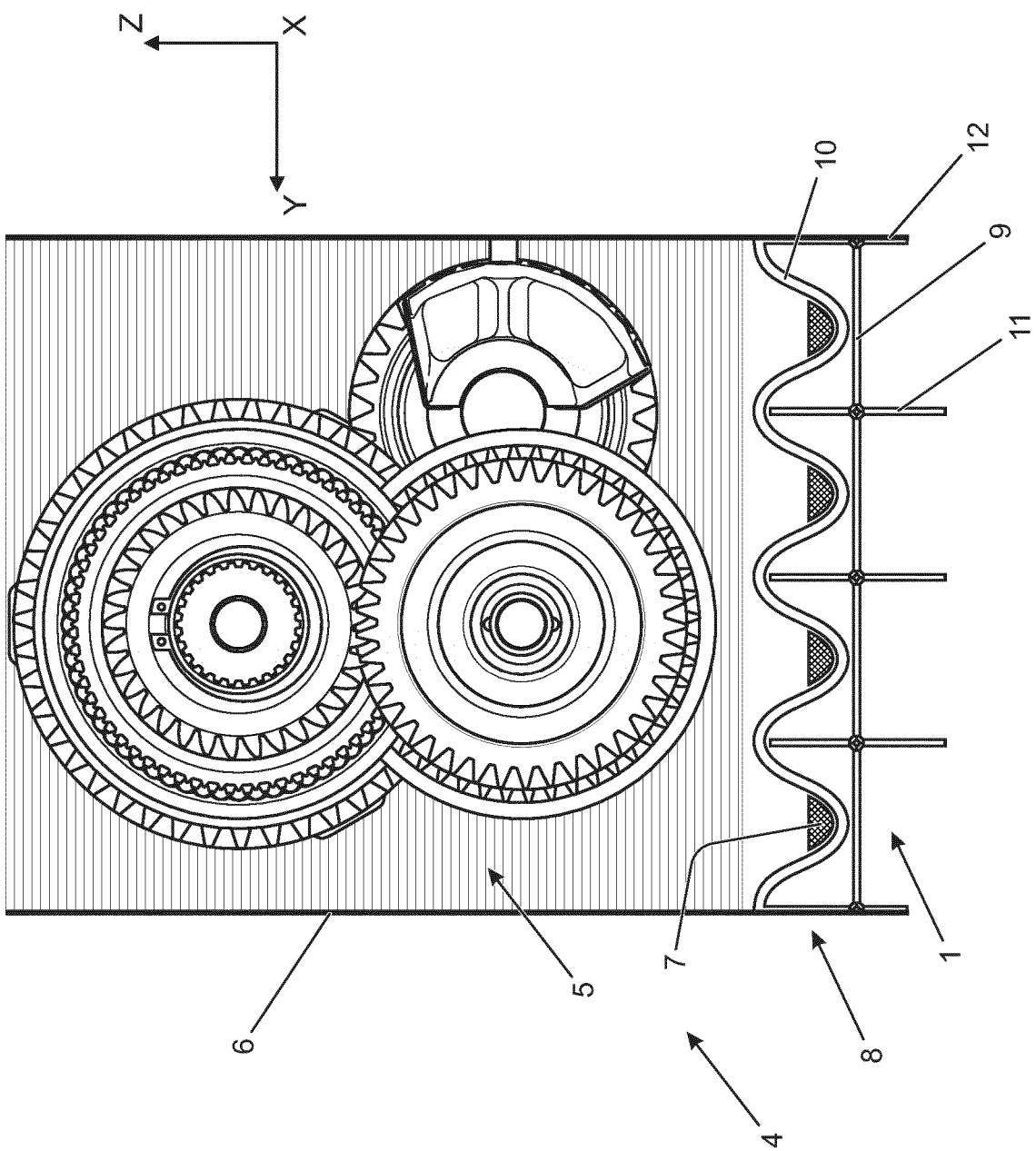


FIG. 2

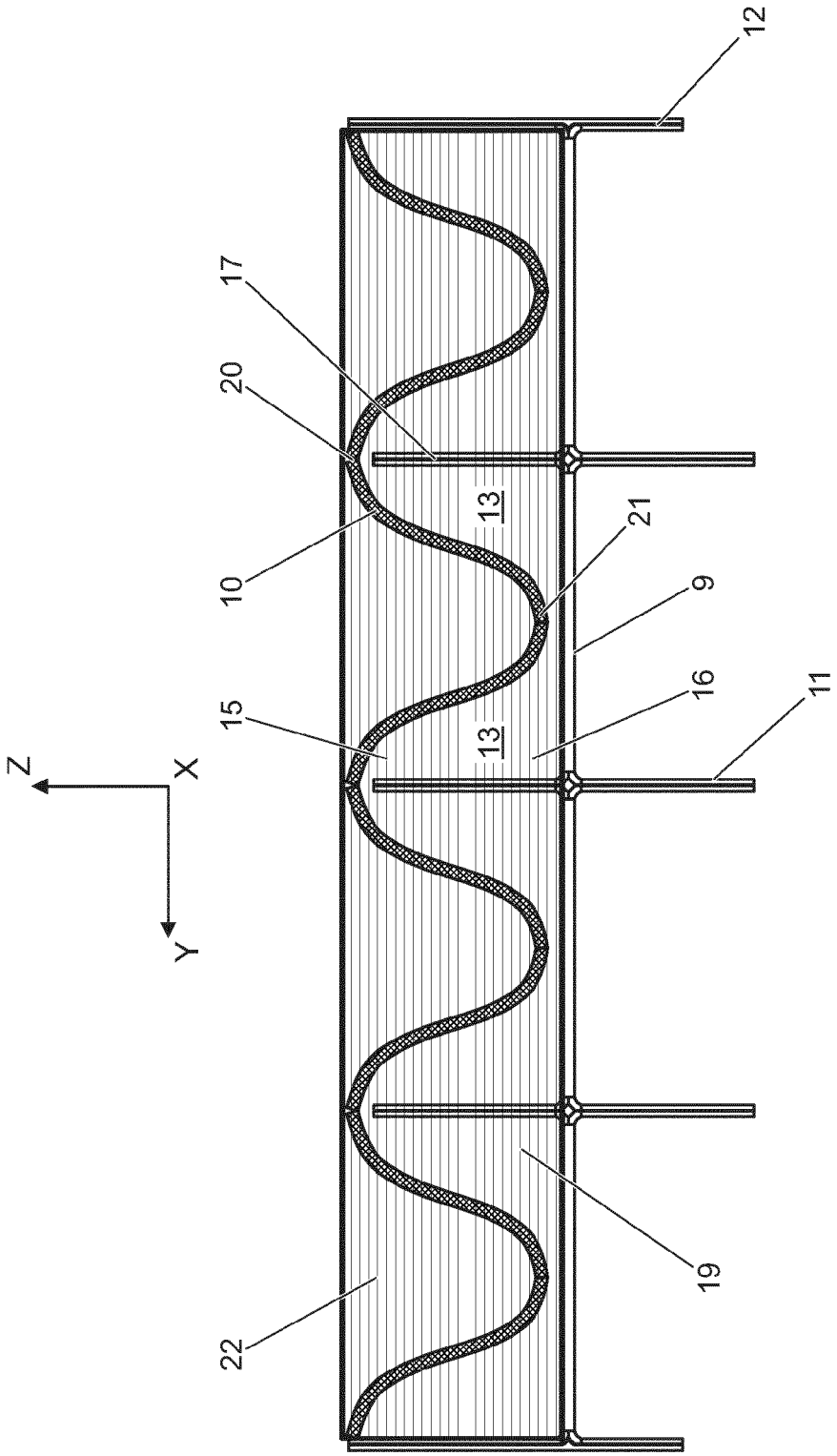


FIG. 3

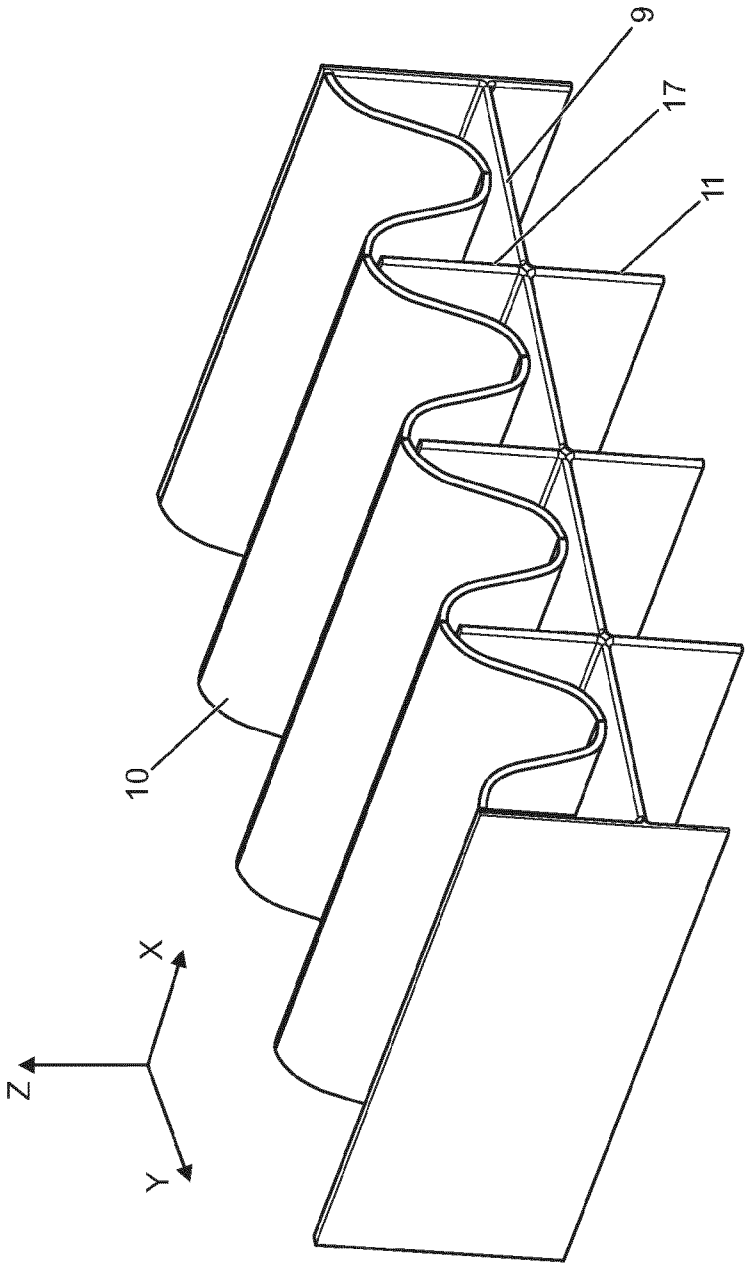


FIG. 4

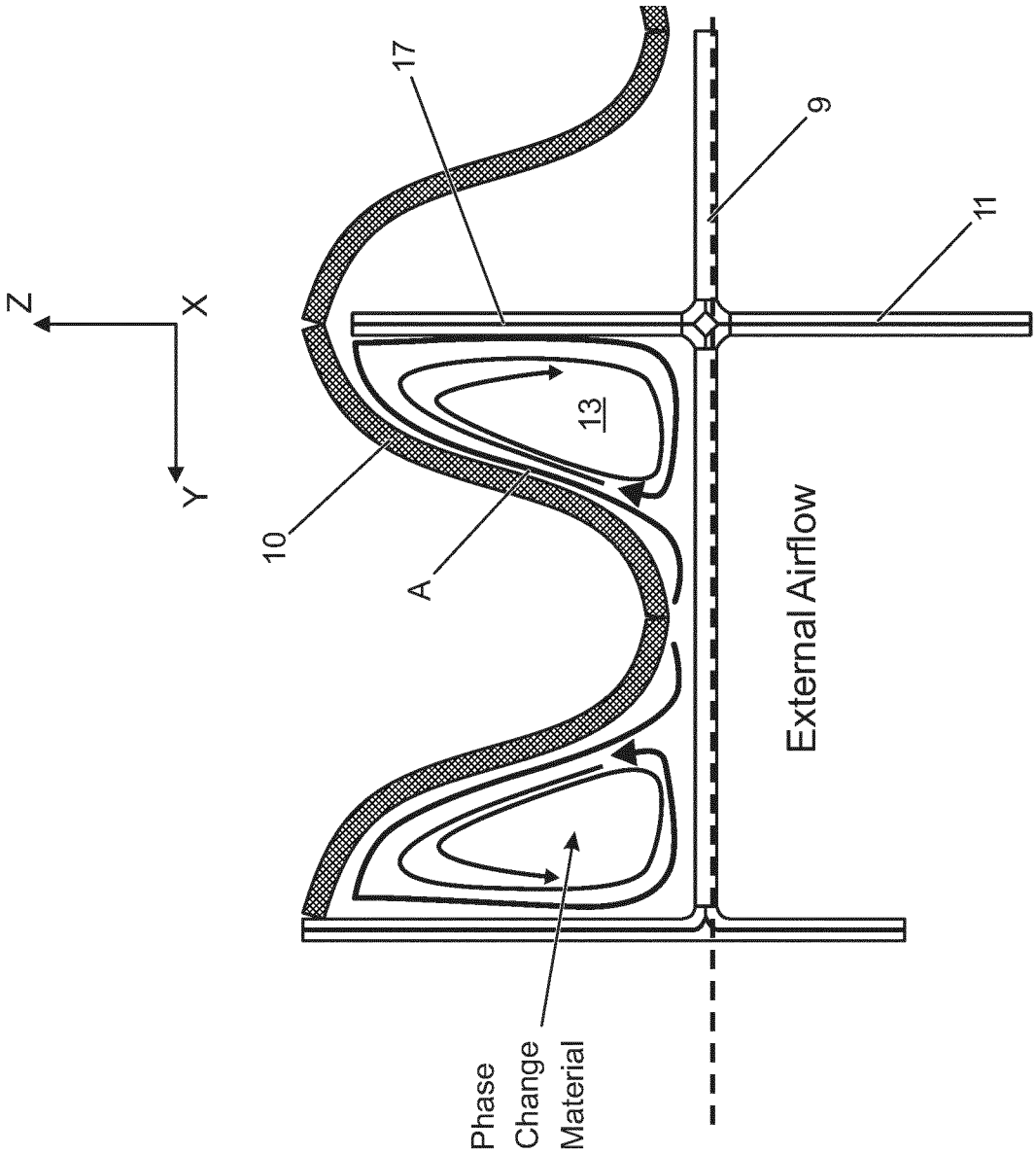


FIG. 5

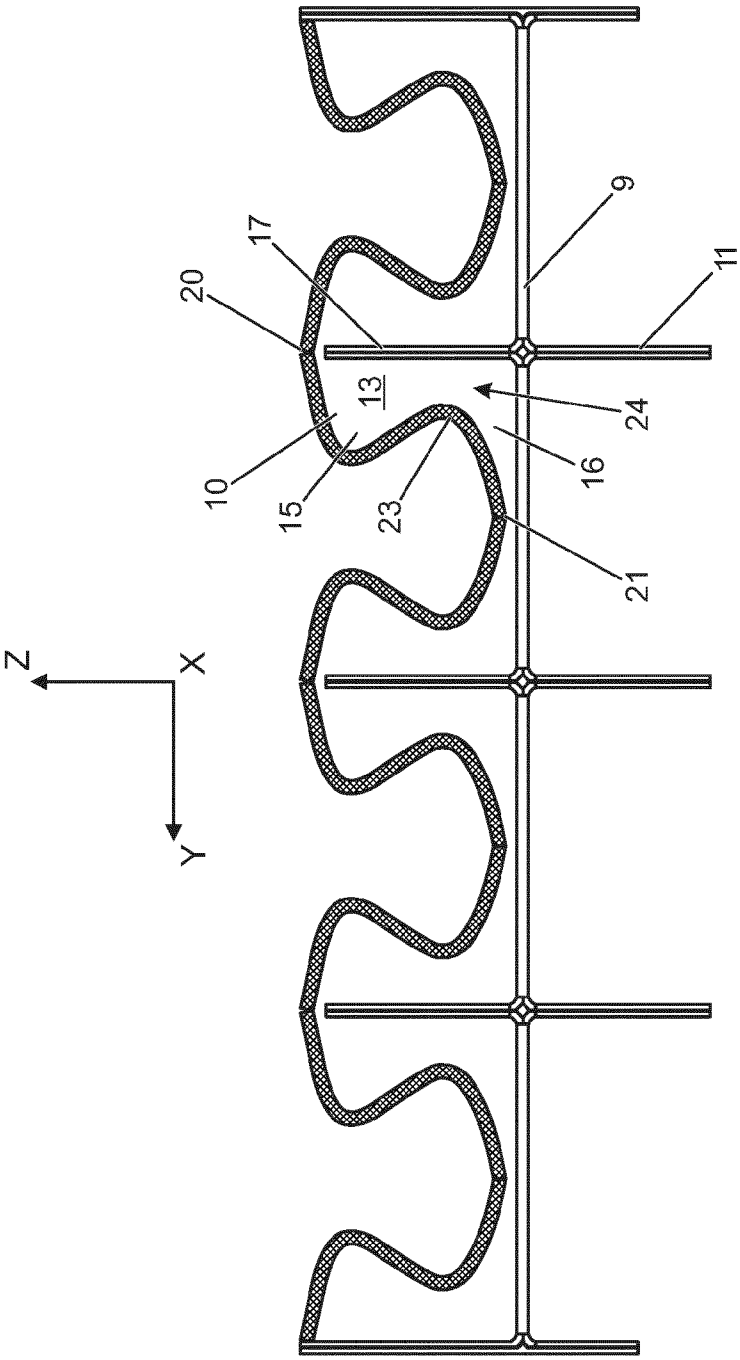


FIG. 6

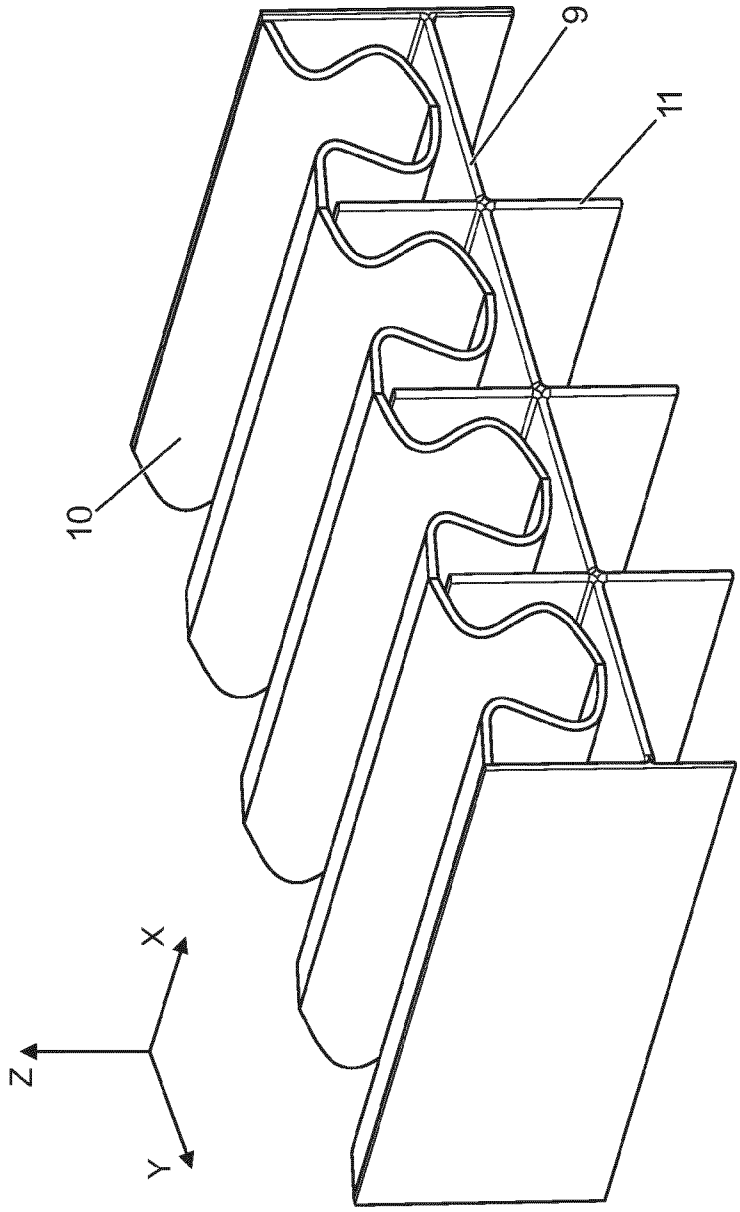


FIG. 7

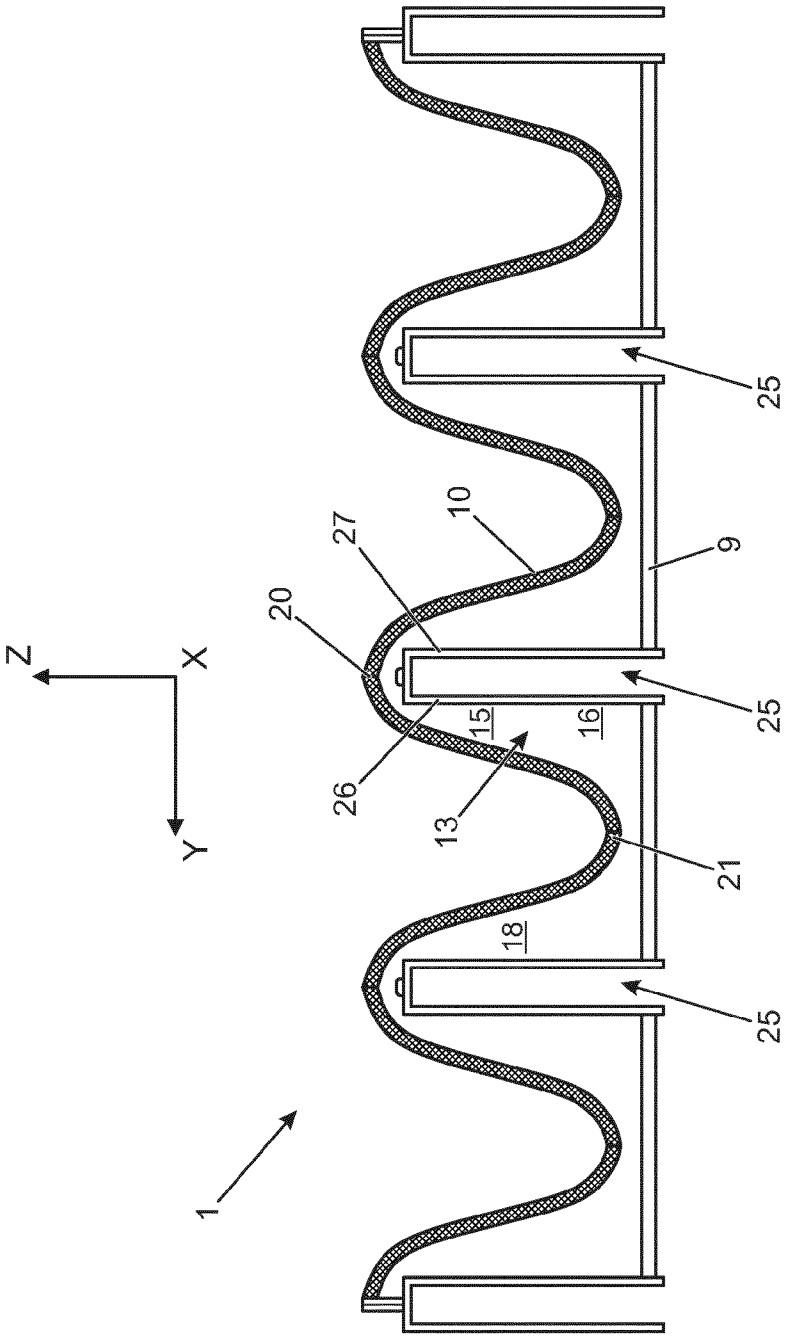


FIG. 8

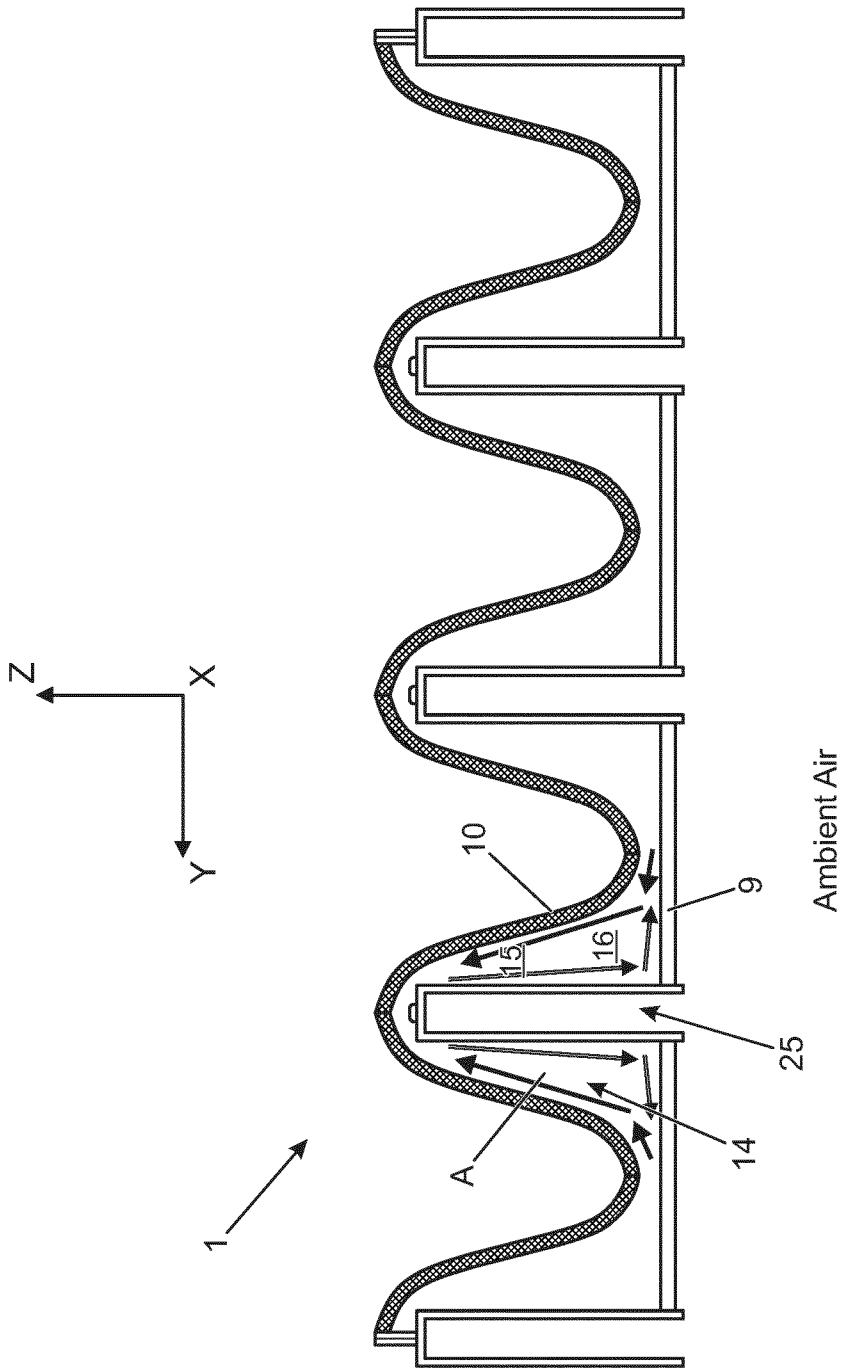


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/080690

A. CLASSIFICATION OF SUBJECT MATTER
INV. F28F3/12 F01P11/08 F01M5/00 F01M11/00 F28D9/00
F28D15/00 F28D20/02
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F28F F01P F01M F28D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 264 970 A1 (JOMA POLYTEC KUNSTSTOFFTECHNIK [DE]) 11 December 2002 (2002-12-11) figures 2-6	1-19
X	FR 2 367 921 A1 (FIAT SPA [IT]) 12 May 1978 (1978-05-12) figure 1	1-19
X	US 2008/275534 A1 (NOEL THOMAS P [US]) 6 November 2008 (2008-11-06) figure 13	1-17
X	US 2 782 008 A (CAUGHILL ROBERT F) 19 February 1957 (1957-02-19) figure 3	1-6, 17-19

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 March 2017	31/03/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Mellado Ramirez, J

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/080690

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 058 898 A (FREESE V CHARLES EDWIN [US]) 9 May 2000 (2000-05-09) the whole document	1-19

1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2016/080690

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 20, 21
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Continuation of Box II.2

Claims Nos.: 20, 21

Claims 20 and 21 define their subject-matter with reference to the drawings, therefore no definite specific constructional features can be deducted from these claims.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guidelines C-IV, 7.2), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2016/080690

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1264970 A1	11-12-2002	AT 294320 T	15-05-2005
		DE 10124071 A1	05-12-2002
		EP 1264970 A1	11-12-2002
FR 2367921 A1	12-05-1978	AR 211663 A1	15-02-1978
		DE 2745931 A1	27-04-1978
		FR 2367921 A1	12-05-1978
		GB 1531109 A	01-11-1978
		IT 1071519 B	10-04-1985
		US 4150655 A	24-04-1979
US 2008275534 A1	06-11-2008	NONE	
US 2782008 A	19-02-1957	NONE	
US 6058898 A	09-05-2000	AU 749469 B2	27-06-2002
		BR 9905692 A	29-08-2000
		CA 2283037 A1	28-06-2000
		EP 1016776 A1	05-07-2000
		JP 2000192807 A	11-07-2000
		KR 20000047595 A	25-07-2000
		US 6058898 A	09-05-2000