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**(54) A HEAT EXCHANGER**

(57) A heat exchanger (200) comprising a housing (202) defined by at least two housing plates (204a, 204b); a heat exchanger core (206) comprising at least two tubes (208-1, 208-2) arranged on one above another with a space therebetween; and at least one turbulator (250) positioned between the tubes (208-1, 208-2) and comprising a sheet (210) a plurality of integral rows (212) of alternating of first crests (216) and second crests (218). The first crests (216) are protruded beyond a first plane (215) in a first direction, and the second crests (218) are protruded beyond the first plane (215) in a second direction. An outer edge portion (217) of each first crest (216) of at least one side row (212-1, 212-N) is distorted, and adapted to be received in a first gap between a curved portion (226) of the corresponding tube (208-1, 208-2) and the corresponding housing plate (204a, 204b).

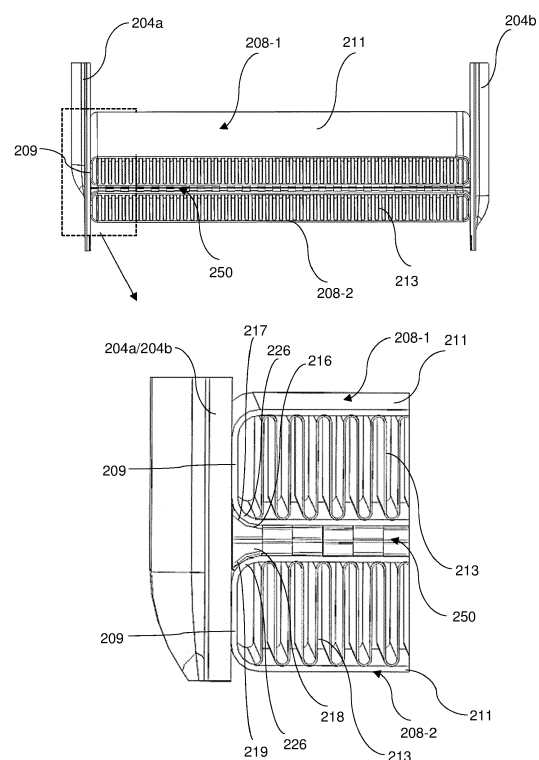


FIG. 5

## Description

### FIELD OF INVENTION

**[0001]** The present invention relates to a heat exchanger. More specifically, the present invention relates to an improved turbulator for the heat exchanger.

### BACKGROUND OF THE INVENTION

**[0002]** As is well known that in order to achieve high volumetric efficiency, improved performance and power of a motor vehicle's combustion engine, the combustion engine is supplied with charge air that has been compressed using a turbocharger or supercharger. However, this compression has the effect of raising the charge air temperature and reducing its density. For this reason, the charge air has to be cooled before it is introduced into the combustion chambers of the engine. Generally, cooling is performed in an air cooler or a heat exchanger known as a charge air cooler or intercooler. The drop in the temperature of charge air allows a reduction of the risks of auto-ignition and makes it possible to improve the density of the charge air, which enhances the combustion yield.

**[0003]** A conventional charge air cooler, such as a water-cooled charge air cooler (WCAC), may include a housing defined by walls, such a side wall 102, to receive a plurality of tubes, such as tubes 104 and 106, as shown in FIG. 1. Opposite ends of the tubes are inserted in the tube slots of headers and further brazed to the respective headers. The housing is generally open at its two ends so that the tubes can be connected to a fluid inlet tank and a fluid outlet tank. The fluid such as air to be cooled flows through air flow passages defined by the tubes 104 and 106. Generally, air turbulators, such as an air tabulator 107, are provided in the air flow passages of the tubes. In addition, a coolant turbulator, such as a tabulator 108, is provided between adjacent tubes, i.e. adjacent tubes are separated by the coolant turbulator. The charge air flows in the tubes from the inlet tank toward the outlet collecting tank, and the coolant fluid, such as water, flows around the tubes through the spacing between adjacent tubes separated by the coolant tabulators, from an inlet pipe toward an outlet pipe, and exchanges heat with the charge air to cool the charge air. Such a coolant turbulator 108 is formed of a sheet comprising a plurality of integral rows of alternating crests and valleys to turn a laminar flow of the coolant into a turbulent one and, in turn, to increase the heat exchange efficiency.

**[0004]** In addition, with engine downsizing and need of increasing engine performance the mechanical load of the engine component is increasing more and more severe. The thermal shock load experience by the engine component is increasing because of requirement of more and more severe targets and/or requirements. On tube design of the WCAC, the one of the main failure mode is due to thermal shock located at tube and header connection. More precisely, a location where there is thick-

ness variation between the tube and the header slot at hot side of the WCAC, i.e., air inlet and coolant outlet side. As shown in FIG. 1, there is a gap or bypass 110 between the side wall 102 of the housing, tubes 104/106 and an edge of the coolant turbulator 108, where the coolant can flow without any physical restriction and avoid passing through the coolant turbulator 108 which leads to significant temperature difference between air side and coolant side of the tube. The thickness variation together with significant temperature difference between air and coolant side of the tube, may create local stress concentration with high load during the thermal shock phenomena in the WCAC, which may leads to failure of the heat exchanger.

**[0005]** Therefore, there is need of a solution to prevent to eliminate areas with significantly high local temperature differences between the air and coolant side to reduce thermal stress on the tubes. Further, there is a need to improve the resistance of the tube portion corresponds to air inlet side and coolant outlet side to the thermal shock phenomena.

### SUMMARY OF THE INVENTION

**[0006]** The present invention discloses a simple, efficient, and robust heat exchanger, such as a water-cooled charge air cooler (WCAC), for a motor vehicle. Particularly, the present invention discloses an improved turbulator for the WCAC.

**[0007]** In accordance with an embodiment of the present invention, the disclosed turbulator comprises a sheet of a material, the sheet comprising a plurality of integral rows, along a first axis, of alternating of first crests and second crests. The first crests are protruded beyond a first plane in a first direction. The second crests are protruded beyond the first plane in a second direction opposite to the first direction. At least a portion of each first crest of at least one side row of the plurality of rows is protruded beyond a second plane that is offset to the first plane and coplanar to the first crests of the neighboring rows.

**[0008]** In addition, an outer edge portion of each first crest of the side row is distorted and protruded beyond the second plane in the first direction.

**[0009]** In an embodiment, at least a portion of each second crest of the side row is protruded beyond a third plane that is offset to the first plane and coplanar to the second crests of the neighboring rows.

**[0010]** In addition, an outer edge portion of each second crest of the side row is distorted and protruded beyond the third plane in the second direction.

**[0011]** Further, adjacent first crests and second crests in each row of the plurality of rows are connected by stepped side walls.

**[0012]** Furthermore, adjacent first crests and the second crests of each rows are arranged in an inverted manner with respect to each other.

**[0013]** In addition, at least one perforation is provided between two neighboring rows of the plurality of rows

such that that the second crests in each row are in fluid communication with adjacent first crests in any immediately adjacent row, and the first crests in the row are in fluid communication with adjacent second crests in the immediately adjacent row.

**[0014]** The first crests in one of the rows are configured adjacent to the second crests in any immediately adjacent row, and the second crests in one of the rows are configured adjacent to the first crests in the immediately adjacent row.

**[0015]** In an embodiment, the first plane is extended in a manner to divide the turbulator in two symmetric half parts.

**[0016]** In accordance with another embodiment, the present invention discloses a heat exchanger for a motor vehicle. The heat exchanger comprises a housing defined by at least two housing plates and a heat exchanger core adapted to be received in the housing. The heat exchanger core comprises at least two tubes arranged on one above another with a space therebetween to define a fluid flow passage for a fluid, wherein opposite smaller side walls of the two tubes abut with inner surfaces of the corresponding housing plates. The heat exchanger further comprises at least one turbulator positioned between the tubes. The turbulator comprises a sheet of a material. The sheet comprises a plurality of integral rows, along a first axis, of alternating of first crests and second crests. The first crests are protruded beyond a first plane in a first direction. The second crests are protruded beyond the first plane in a second direction opposite to the first direction. The first crests and second crests are adapted to abut with adjacent outer surfaces of the respective tubes.

**[0017]** At least a portion of each first crest of at least one side row of the plurality of rows is protruded beyond a second plane that is offset to the first plane and coplanar to the first crests of the neighboring row. In addition, an outer edge portion of each first crest of the side row is distorted and protruded beyond the second plane. The distorted outer edge portion is adapted to be received in a first gap between a curved portion of the corresponding tube and the corresponding housing plate.

**[0018]** In addition, the distorted outer edge portion of each first crest of the side row has a curved profile complementary to the curved portion of the corresponding tube.

**[0019]** In an embodiment, at least a portion of each second crest of the side row is protruded beyond a third plane that is offset to the first plane and coplanar to the second crests of the neighboring rows.

**[0020]** Besides, an outer edge portion of each second crest of the side row is distorted and protruded beyond the second plane. The distorted outer edge portion being adapted to be received in a second gap between a curved portion of the corresponding tube and the corresponding housing plate.

**[0021]** The distorted outer edge portion of each second crest of the side row has a curved profile complementary

to the curved portion of the corresponding tube.

**[0022]** In the present description, some elements or parameters may be indexed, such as a first element and a second element. In this case, unless stated otherwise, this indexation is only meant to differentiate and name elements which are similar but not identical. No idea of priority should be inferred from such indexation, as these terms may be switched without betraying the invention. Additionally, this indexation does not imply any order in mounting or use of the elements of the invention.

## BRIEF DESCRIPTION OF DRAWINGS

**[0023]** Other characteristics, details and advantages of the invention may be inferred from the description of the invention hereunder. A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying figures, wherein:

FIG. 1 illustrates a conventional heat exchanger showing a coolant bypass area between a side wall of the housing, tubes and an edge of a coolant turbulator, in accordance with an embodiment of the present invention;

FIG. 2 illustrates an isometric view of a heat exchanger, in accordance with an embodiment of the present invention;

FIG. 3 illustrates a sectional view of the heat exchanger of FIG. 2;

FIG. 4 illustrates a turbulator of the heat exchanger of FIG. 2; and

FIG. 5 illustrates an arrangement of the turbulator between two tubes of the heat exchanger of FIG. 2.

## DETAILED DESCRIPTION

**[0024]** It must be noted that the figures disclose the invention in a detailed enough way to be implemented, said figures helping to better define the invention if needs be. The invention should however not be limited to the embodiment disclosed in the description.

**[0025]** The present invention is explained in the forthcoming description and the accompanying drawings with an example of a heat exchanger such as a water-cooled charge air cooler for a motor vehicle. More specifically, the present invention discloses an improved turbulator for the heat exchanger, wherein the shape of a portion of the turbulator is modified for closing the coolant channel by-pass area to prevent bypass flow of the coolant and forcing the coolant to flow through the main core area of the heat exchanger and/or the turbulator. Because of

that, the coolant temperature is highly improved in the most critical area, i.e., air inlet side and coolant outlet side, in terms of thermal shock phenomena, thereby eliminating the areas with significantly high local temperature differences, which reduces the thermal stress during normal vehicle operation, thereby reducing failure caused by thermal shock phenomena and increasing durability of the WCAC. In addition, mechanical core resistance is also improved as the brazing area between the turbulator and the tubes is extended to the tube radius.

**[0026]** It is to be appreciated that the concept of the present invention is applicable for any other application in vehicular and non-vehicular environment, where it is required to provide a modified turbulator for closing a coolant channel by-pass area in heat exchangers.

**[0027]** Referring to FIG. 2 and FIG. 3, in accordance with an embodiment, the present invention discloses a heat exchanger 200, such as a water-cooled charge air cooler, for a motor vehicle. The heat exchanger 200 includes a housing 202, a first tank 203a, such as an inlet tank, and a second tank 203b, such as an outlet tank. The first tank 203a and the second tank 203b are fluidically connected to housing 202 through the two opposite open ends of the housing 202. The housing 202 is configured to accommodate a heat exchanger core 206. The housing 202 is defined by two side housing plates 204a and 204b configured on two opposite sides of the heat exchanger core 206, and two closing plates 205a and 205b configured on other two side of the heat exchanger core 206 adjacent to the housing plates 204a and 204b to cover the heat exchanger core 206 from other two opposite sides. The longitudinal side ends of the closing plates 205a and 205b abut with adjacent longitudinal side ends of the housing plates 204a and 204b.

**[0028]** The heat exchanger core 206 includes a plurality of tubes 208-1, 208-2...208-N (hereinafter, collectively referred to as tubes 208), and a plurality of turbulators 250 arranged between the tubes 208. The plurality of tubes 208 and the plurality of turbulators 250 are arranged alternatively such that at least one turbulator 250 is configured between the adjacent tubes and a space or a flow passage for a fluid/coolant is created between the adjacent tubes. Each of the tubes 208 has opposite large flat walls 211 that are connected by rounded/curved and smaller sidewalls 209 at their ends. A portion of the smaller side walls 209 of the tubes 208 abuts with inner surfaces of the corresponding housing plates 204a and 204b. In addition, opposite open ends of the tubes 208 are inserted in tube slots of headers 223a and 223b configured on the two open ends of the housing 202 and further brazed to the respective headers 223a and 223b. The first tank 203a and the second tank 203b are secured to the respective headers 223a and 223b so that the fluid, such as charge air, to be cooled flows through airflow passage defined by each of the tubes 208 from the first tank 203a to the second tank 203b.

**[0029]** In addition, one or more air turbulators 213 are

inserted in the airflow passage of each of the tubes 208. The air turbulators 213 can be lanced and offset fins. Generally, crests of the air turbulators 213 are joined to the inner surfaces of the respective tubes 208 by a suitable joining process such as, but not limited to, soldering, brazing, and welding.

**[0030]** The fluid/coolant, such as water, is received inside the housing 202 through an inlet pipe 225a and flows around the tubes 208 through the spacing/fluid flow passages between adjacent tubes separated by the coolant tabulators 250, exchanges heat with the charge air to cool the charge air, and further egress the housing 202 through an outlet pipe 225b. For instance, the inlet pipe 225a is configured on the housing plates 204b and the outlet pipe 225b is configured on the housing plates 204a.

**[0031]** With such arrangement of the tubes 208 separated by the tabulators 250, air flowing through the tubes 208 and the coolant/ water flowing through the spacing between the tubes 208, the coolant flow passages are adjacent to the air flow passages. Such configuration enables heat exchanger between the air flowing through the air flow passages in the tubes 208 and the coolant flowing through the coolant flow passages around the tubes. The air tabulators 213 and the coolant turbulators 250 are made of thermal conductive material and are used as means to enhance heat exchange between the air stream and coolant/water. In addition, the air tabulators 213 and the coolant turbulators 250 are adapted to turn a laminar flow of the air and coolant, respectively, into a turbulent one and, in turn, to increase the heat exchange efficiency of the heat exchanger 200.

**[0032]** It is to be appreciated that construction and function of the turbulators 250 are similar, therefore one of the turbulators will be described below and that will be sufficient to describe all similar turbulators.

**[0033]** Referring to FIG. 4, the turbulator 250 comprises a sheet 210 of a material having good thermal conductivity, such as a sheet of steel, copper, brass, aluminum, and the like. For instance, the turbulators 250 can be made through stamping process. The sheet 210 includes a plurality of integral rows 212-1, 212-2...212-N (herein after, collectively referred to as rows 212), along a first axis 214, of alternating of first crests 216 and second crests 218. The first crests 216 are protruded beyond a first plane (indicated by dash-dotted line 215) in a first direction, whereas the second crests 218 are protruded beyond the first plane 215 in a second direction opposite to the first direction. The first plane 215 can be extended in a manner to divide the turbulator 250 in two symmetric half parts. In addition, adjacent first crests 216 and the second crests 218 of each rows 212 can be arranged in an inverted manner with respect to each other. For instance, in each of the rows 212, the first crests 216 and the second crests 218 are protruded in the opposite directions such that alternate ridges and troughs like structures are formed.

**[0034]** Besides, adjacent first crests 216 and the second crests 218 in each row of the plurality of rows 212 are

connected by stepped side walls 234. The stepped side walls 234 can have one or more bends. The length of the stepped side walls 234 can be different in the different rows. For instance, the lengths of the stepped side walls 234 in the row 212-1 can be longer than that of the stepped side walls 234 in the row 212-2.

**[0035]** In addition, the first crests 216 and the second crests 218 are adapted to abut with adjacent outer surfaces of the respective tubes 208. For instance, the first crests 216 abut with the outer surface of the tube 208-1 and the second crests 218 abut with the outer surface of the tube 208-2, as shown in FIG. 4. In addition, the first crests 216 and the second crests 218 can be joined/brazed to the outer surfaces of the respective tubes 208.

**[0036]** In an embodiment, at least a portion of each first crest 216 of at least one side row, such as but not limited to side rows 212-1 and 212-N, is protruded beyond a second plane 220 (indicated by a solid line 220 in FIG. 4). The second plane 220 is offset to the first plane 215 and coplanar to the first crests 216 of the neighboring row of the side rows 212-1 and 212-N. An outer edge portion 217 of each first crest 216 of the side rows 212-1 and 212-N is distorted and protruded beyond the second plane 220. In addition, the distorted outer edge portions 217 of the first crest 216 are adapted to be received in a first gap between a curved portion 226 of the small side wall 209 of the corresponding tube, such as tube 208-1, and the corresponding housing plate 204a, 204b, as shown FIG. 5. Besides, the distorted outer edge portion 217 of each first crest 216 of the side rows 212-1 and 212-N has a curved profile complementary to the curved portion 226 of the corresponding tube 208-1/208-2, as shown in FIG. 5.

**[0037]** In another embodiment, at least a portion of each second crest 218 of the side rows 212-1 and 212-N can be protruded beyond a third plane (indicated by dash line 228 in FIG. 4). The third plane 228 is offset to the first plane 215 and coplanar to the second crests 218 of the neighboring rows of the side rows 212-1 and 212-N. An outer edge portion 219 of each second crest 218 of the side rows 212-1 and 212-N can be distorted and protruded beyond the second plane 218. The distorted outer edge portions 219 of the second crests 218 are adapted to be received in a second gap between a curved portion 226 of the corresponding tube, such as tube 208-2, and the corresponding housing plate 204a, 204b, as shown in FIG. 5. Besides, the distorted outer edge portion 219 of each second crest 218 of the side rows 212-1 and 212-N has a curved profile complementary to the curved portion 226 the small side wall 229 of the corresponding tube 208-1/208-2.

**[0038]** As the distorted outer edge portions 217 of the first crest 216 and the distorted outer edge portions 219 of the second crests 218 are inserted in the gaps, including the first and second gaps, between the side housing plates 204a and 204b, and the curved portions 226 of the respective tubes 208, the turbulator 250 closed the coolant channel by-pass area to prevent bypass flow of

the coolant and forces the coolant/water to flow through the core area of the heat exchanger core 206 and/or the turbulator 250. Such configuration of the turbulator 250 facilitates complete removal of areas with high temperature differences which is generated by the by-pass coolant flow in the conventional heat exchanger. Because of that, the thermal stress during normal vehicle operation can be reduced, thereby reducing failure caused by thermal shock phenomena of the heat exchanger 200.

In addition, more uniform temperature profile at the edges of the turbulator 250 on outlet side can be achieved. In addition, uniform temperature profile along the heat exchanger core length can be achieved, i.e. improves temperature uniformity and reduces temperature gradients.

**[0039]** Further, the turbulators 250 also simplify the assembly process as the tubulator deformations, i.e. the distorted outer edge portions 217 and 219 of the first crest 216 and second crests 218, are aligned with the curved portions 226 of the tubes 208 which ensures correct positioning of the turbulator during assembling and brazing process. Additionally, mechanical resistance to the thermal shock of the heat exchanger core 206 is also improved as the brazing area between turbulators 250 and the tubes 208 is increased due to the distorted outer edge portions 217 and 219 extended to the tube curved portions 226. This also increases heat exchanger core resistance to mechanical load such as but not limited to air pressure cycle and coolant pressure cycle, thereby increasing the heat exchanger lifetime.

**[0040]** Referring to FIG. 4 again, at least one perforation is provided between two neighboring rows of the plurality of rows 212 such that that the second crests 218 in each row 212 are in fluid communication with adjacent first crests 216 in any immediately adjacent row, and the first crests 216 in the row are in fluid communication with adjacent second crests 218 in the immediately adjacent row. In addition, the first crests 216 in one of the rows 212 is configured adjacent to the second crests 218 in any immediately adjacent row, and similarly, the second crests 218 in one of the rows 212 are configured adjacent to the first crests 216 in the immediately adjacent row.

**[0041]** In any case, the invention cannot and should not be limited to the embodiments specifically described in this document, as other embodiments might exist. The invention shall spread to any equivalent means and any technically operating combination of means.

## Claims

1. A turbulator (250) comprising:

a sheet (210) of a material, the sheet (210) comprising a plurality of integral rows (212), along a first axis (214), of alternating of first crests (216) and second crests (218), the first crests (216) being protruded beyond a first plane

- (215) in a first direction, and the second crests (218) being protruded beyond the first plane (215) in a second direction opposite to the first direction;  
 wherein at least a portion of each first crest (216) of at least one side row (212-1, 212-N) of the plurality of rows (212) is protruded beyond a second plane (220) that is offset to the first plane (215) and coplanar to the first crests (216) of the neighboring rows.
2. The turbulator (250) as claimed in the preceding claim, wherein an outer edge portion (217) of each first crest (216) of the side row (212-1, 212-N) is distorted and protruded beyond the second plane (220) in the first direction.
  3. The turbulator (250) as claimed in any of the preceding claims, wherein at least a portion of each second crest (218) of the side row (212-1, 212-N) is protruded beyond a third plane (228) that is offset to the first plane (215) and coplanar to the second crests (218) of the neighboring rows.
  4. The turbulator (250) as claimed in any of the preceding claims, wherein an outer edge portion (219) of each second crest (218) of the side row (212-1, 212-N) is distorted and protruded beyond the third plane (228) in the second direction.
  5. The turbulator (250) as claimed in any of the preceding claims, wherein adjacent first crests (216) and second crests (218) in each row of the plurality of rows (212) are connected by stepped side walls (234).
  6. The turbulator (250) as claimed in any of the preceding claims, wherein adjacent first crests (216) and the second crests (218) of each rows (212) are arranged in an inverted manner with respect to each other.
  7. The turbulator (250) as claimed in any of the preceding claims, wherein at least one perforation is provided between two neighboring rows of the plurality of rows (212) such that the second crests (218) in each row (212) are in fluid communication with adjacent first crests (216) in any immediately adjacent row, and the first crests (216) in the row are in fluid communication with adjacent second crests (218) in the immediately adjacent row.
  8. The turbulator (250) as claimed in any of the preceding claims, wherein the first crests (216) in one of the rows (212) are configured adjacent to the second crests (218) in any immediately adjacent row, and wherein the second crests (218) in one of the rows (212) are configured adjacent to the first crests (216) in the immediately adjacent row.
  9. The turbulator (250) as claimed in any of the preceding claims, wherein the first plane (215) is extended in a manner to divide the turbulator (250) in two symmetric half parts.
  10. A heat exchanger (200) for a motor vehicle comprising:
    - a housing (202) defined by at least two housing plates (204a, 204b);
    - a heat exchanger core (206) adapted to be received in the housing (202), the heat exchanger core (206) comprising at least two tubes (208-1, 208-2) arranged on one above another with a space therebetween to define a fluid flow passage for a fluid, opposite smaller side walls (209) of the two tubes (208-1, 208-2) abut with inner surfaces of the corresponding housing plates (204a, 204b); and
    - at least one turbulator (250) positioned between the tubes (208-1, 208-2), the turbulator (250) comprising a sheet (210) of a material, the sheet (210) comprising a plurality of integral rows (212), along a first axis (214), of alternating of first crests (216) and second crests (218), the first crests (216) being protruded beyond a first plane (215) in a first direction, and the second crests (218) being protruded beyond the first plane (215) in a second direction opposite to the first direction, wherein the first crests (216) and second crests (218) are adapted to abut with adjacent outer surfaces of the respective tubes (208-1 and 208-2);
    - wherein at least a portion of each first crest (216) of at least one side row (212-1, 212-N) of the plurality of rows (212) is protruded beyond a second plane (220) that is offset to the first plane (215) and coplanar to the first crests (216) of the neighboring row; and
    - wherein an outer edge portion (217) of each first crest (216) of the side row (212-1, 212-N) is distorted and protruded beyond the second plane (220), and wherein the distorted outer edge portion (217) is adapted to be received in a first gap between a curved portion (226) of the corresponding tube (208-1, 208-2) and the corresponding housing plate (204a, 204b).
  11. The heat exchanger (200) as claimed in the preceding claim, wherein the distorted outer edge portion (217) of each first crest (216) of the side row (212-1, 212-N) has a curved profile complementary to the curved portion (226) of the corresponding tube (208-1, 208-2).
  12. The heat exchanger (200) as claimed in any of the

preceding claims, wherein at least a portion of each second crest (218) of the side row (212-1, 212-N) is protruded beyond a third plane (228) that is offset to the first plane (215) and coplanar to the second crests (218) of the neighboring rows.

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13. The heat exchanger (200) as claimed in any of the preceding claims, wherein an outer edge portion (219) of each second crest (218) of the side row (212-1, 212-N) is distorted and protruded beyond the second plane (218), the distorted outer edge portion (219) being adapted to be received in a second gap between a curved portion (226) of the corresponding tube (208-1, 208-2) and the corresponding housing plate (204a, 204b).
14. The heat exchanger (200) as claimed in any of the preceding claims, wherein the distorted outer edge portion (219) of each second crest (218) of the side row (212-1, 212-N) has a curved profile complementary to the curved portion (226) of the corresponding tube (208-1, 218-2).

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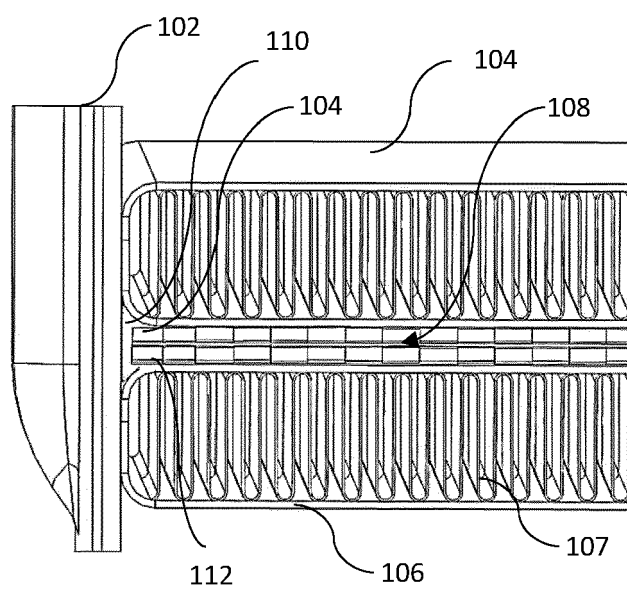


FIG. 1  
(PRIOR ART)

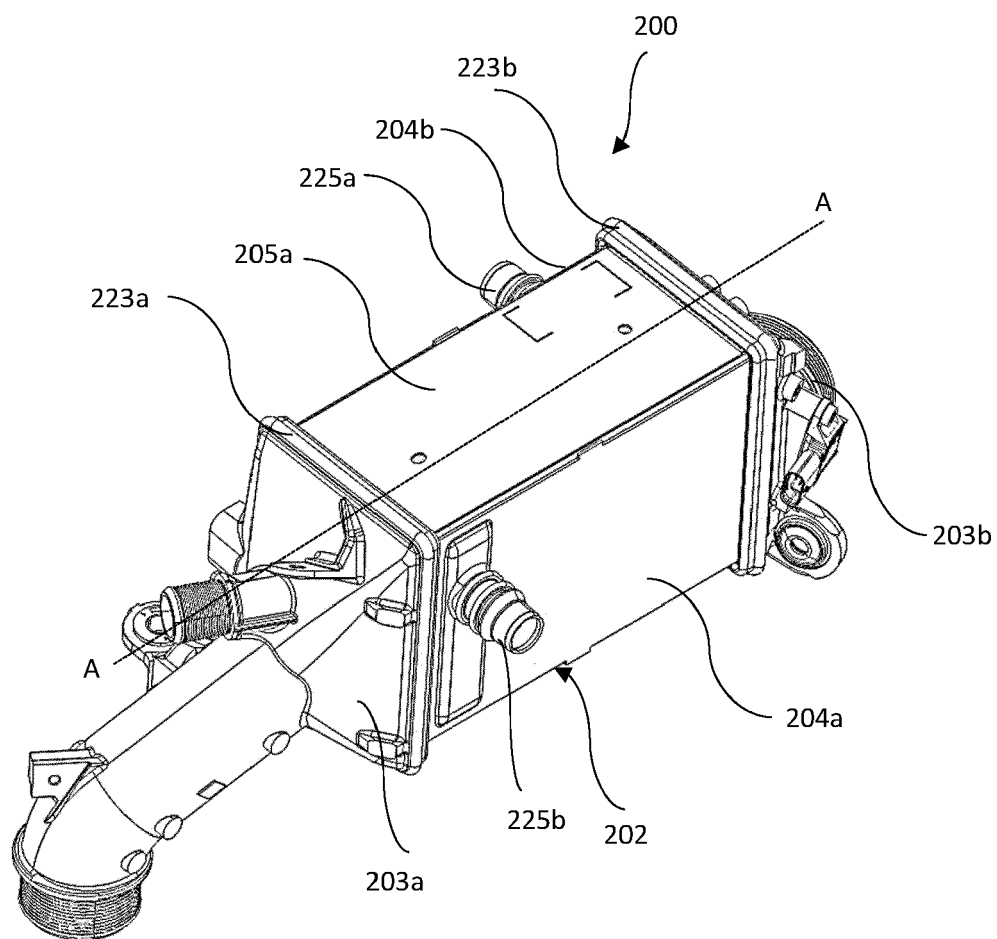
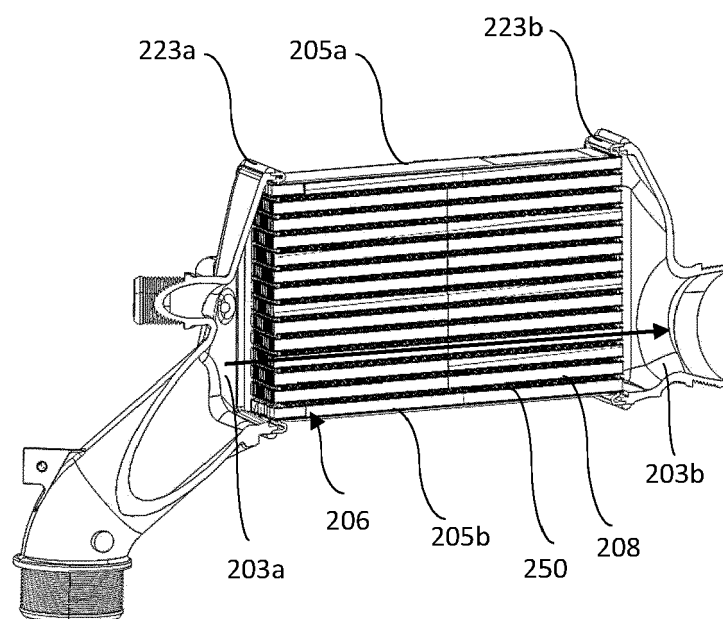


FIG. 2



SECTION A - A

FIG. 3

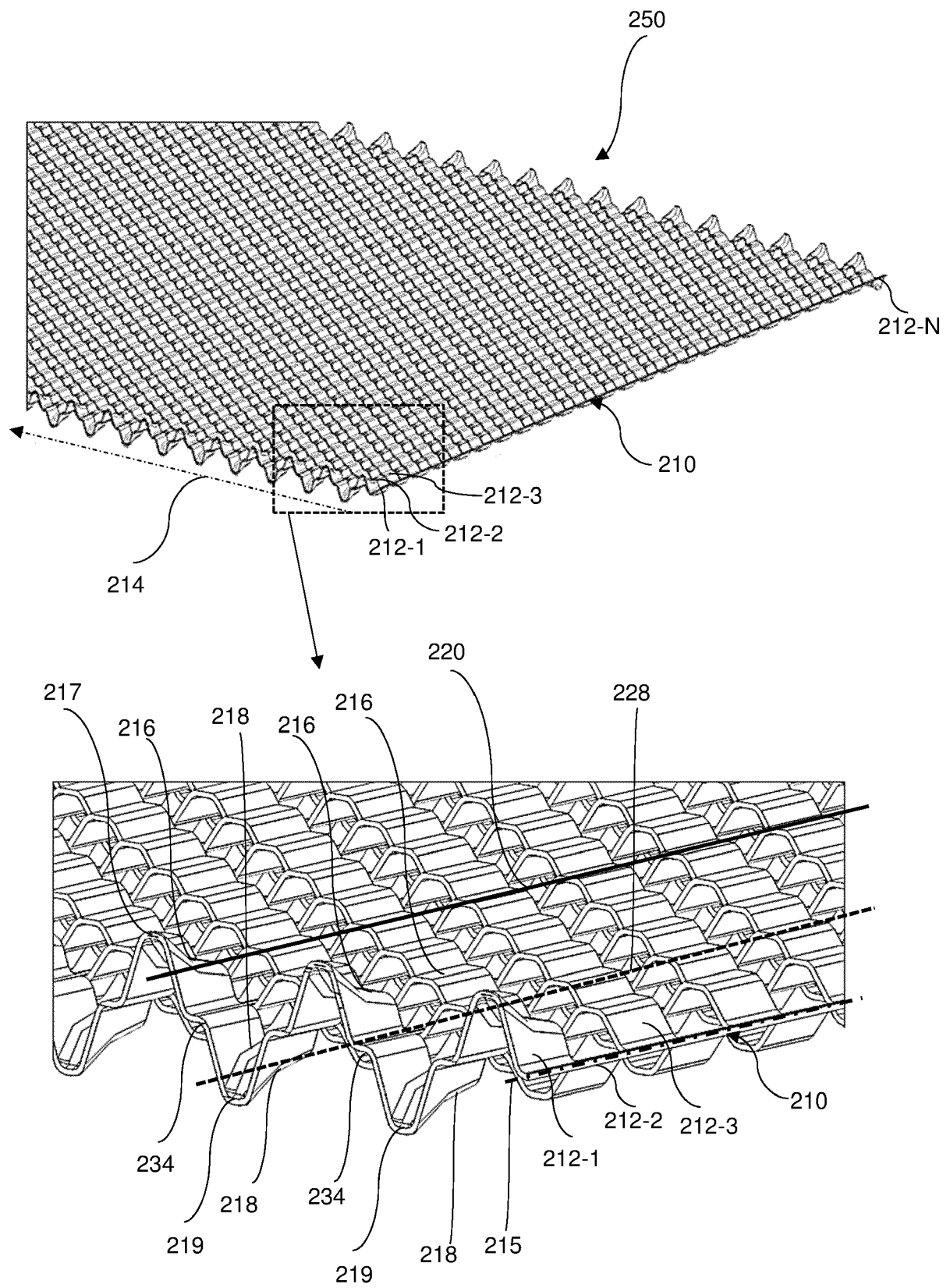


FIG. 4

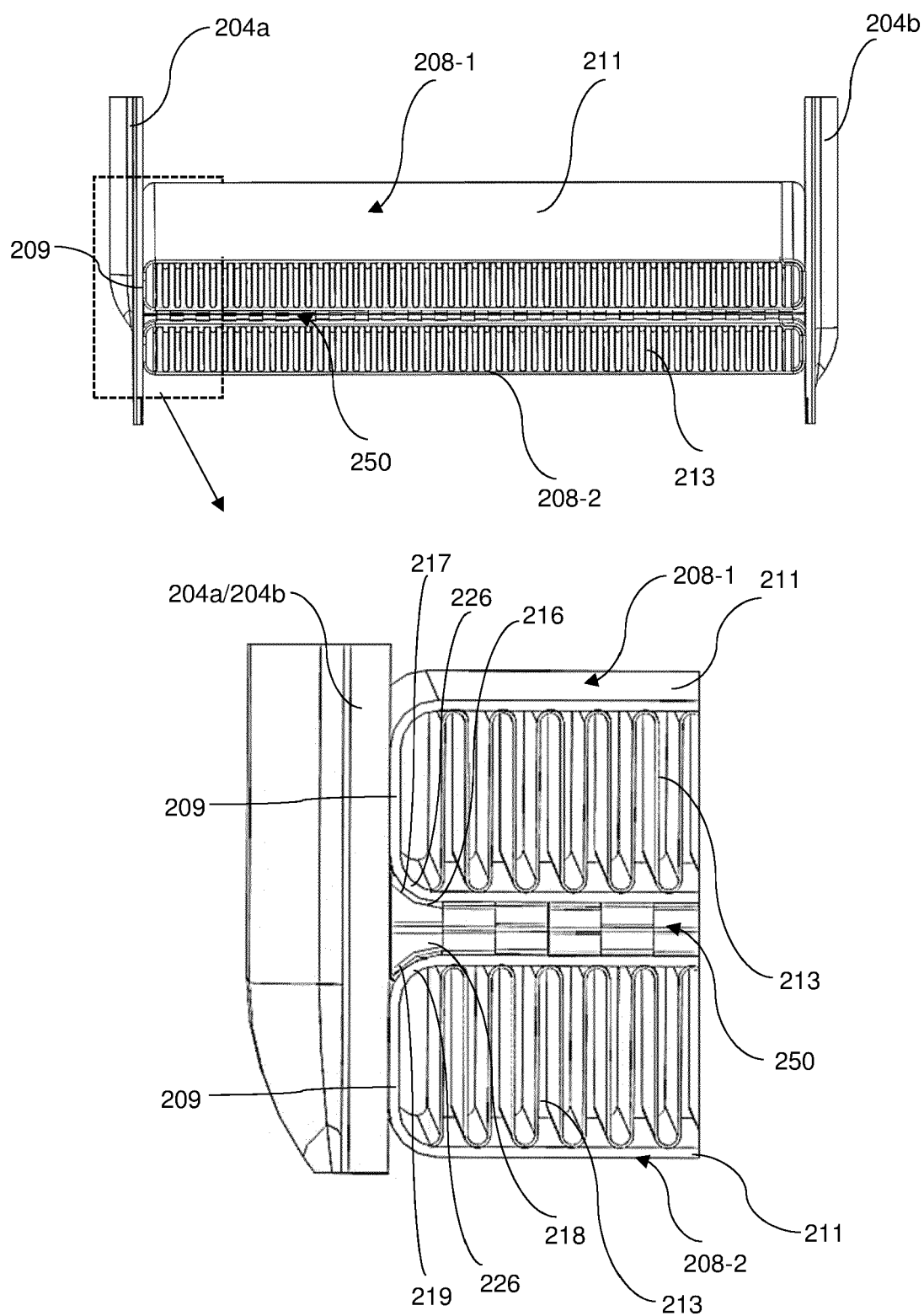


FIG. 5



## EUROPEAN SEARCH REPORT

Application Number

EP 23 19 4433

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category                                                                                                                                                                                                                                                                              | Citation of document with indication, where appropriate, of relevant passages                  | Relevant to claim                | CLASSIFICATION OF THE APPLICATION (IPC) |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|----------------------------------|-----------------------------------------|
| X                                                                                                                                                                                                                                                                                     | DE 103 03 680 A1 (DENSO CORP [JP])<br>7 August 2003 (2003-08-07)                               | 1-9                              | INV.                                    |
| A                                                                                                                                                                                                                                                                                     | * the whole document *                                                                         | 10-14                            | F28F1/40                                |
|                                                                                                                                                                                                                                                                                       | -----                                                                                          |                                  | F28F1/12                                |
| X                                                                                                                                                                                                                                                                                     | US 10 197 336 B2 (CALSONIC KANSEI CORP [JP]) 5 February 2019 (2019-02-05)                      | 1-9                              | F28D7/16                                |
| A                                                                                                                                                                                                                                                                                     | * the whole document *                                                                         | 10-14                            | F02B29/04                               |
|                                                                                                                                                                                                                                                                                       | -----                                                                                          |                                  | F28D21/00                               |
| X                                                                                                                                                                                                                                                                                     | US 10 202 880 B2 (DENSO CORP [JP])<br>12 February 2019 (2019-02-12)                            | 1-9                              | F28F3/02                                |
| A                                                                                                                                                                                                                                                                                     | * the whole document *                                                                         | 10-14                            |                                         |
|                                                                                                                                                                                                                                                                                       | -----                                                                                          |                                  |                                         |
| A                                                                                                                                                                                                                                                                                     | US 2001/027857 A1 (EMRICH KARSTEN [DE] ET AL) 11 October 2001 (2001-10-11)<br>* figures 1-10 * | 1,10                             |                                         |
|                                                                                                                                                                                                                                                                                       | -----                                                                                          |                                  |                                         |
|                                                                                                                                                                                                                                                                                       |                                                                                                |                                  | TECHNICAL FIELDS SEARCHED (IPC)         |
|                                                                                                                                                                                                                                                                                       |                                                                                                |                                  | F28D                                    |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                            |                                                                                                |                                  |                                         |
| Place of search                                                                                                                                                                                                                                                                       |                                                                                                | Date of completion of the search | Examiner                                |
| Munich                                                                                                                                                                                                                                                                                |                                                                                                | 16 January 2024                  | Bloch, Gregor                           |
| CATEGORY OF CITED DOCUMENTS                                                                                                                                                                                                                                                           |                                                                                                |                                  |                                         |
| X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document                                                               |                                                                                                |                                  |                                         |
| T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>.....<br>& : member of the same patent family, corresponding document |                                                                                                |                                  |                                         |

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 23 19 4433

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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35

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55

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|-------------------------------------------|---------------------|----------------------------|---------------------|
| <b>DE 10303680 A1</b>                     | <b>07-08-2003</b>   | <b>DE 10303680 A1</b>      | <b>07-08-2003</b>   |
|                                           |                     | <b>JP 3729136 B2</b>       | <b>21-12-2005</b>   |
|                                           |                     | <b>JP 2003222488 A</b>     | <b>08-08-2003</b>   |
| <hr/>                                     |                     |                            |                     |
| <b>US 10197336 B2</b>                     | <b>05-02-2019</b>   | <b>CN 105247313 A</b>      | <b>13-01-2016</b>   |
|                                           |                     | <b>DE 112014002515 T5</b>  | <b>10-03-2016</b>   |
|                                           |                     | <b>JP 6046558 B2</b>       | <b>14-12-2016</b>   |
|                                           |                     | <b>JP 2014228208 A</b>     | <b>08-12-2014</b>   |
|                                           |                     | <b>US 2016097599 A1</b>    | <b>07-04-2016</b>   |
|                                           |                     | <b>WO 2014188942 A1</b>    | <b>27-11-2014</b>   |
| <hr/>                                     |                     |                            |                     |
| <b>US 10202880 B2</b>                     | <b>12-02-2019</b>   | <b>CN 106233088 A</b>      | <b>14-12-2016</b>   |
|                                           |                     | <b>DE 112015001899 T5</b>  | <b>02-02-2017</b>   |
|                                           |                     | <b>JP 6303755 B2</b>       | <b>04-04-2018</b>   |
|                                           |                     | <b>JP 2015206535 A</b>     | <b>19-11-2015</b>   |
|                                           |                     | <b>US 2017107883 A1</b>    | <b>20-04-2017</b>   |
|                                           |                     | <b>WO 2015162897 A1</b>    | <b>29-10-2015</b>   |
| <hr/>                                     |                     |                            |                     |
| <b>US 2001027857 A1</b>                   | <b>11-10-2001</b>   | <b>NONE</b>                |                     |
| <hr/>                                     |                     |                            |                     |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82