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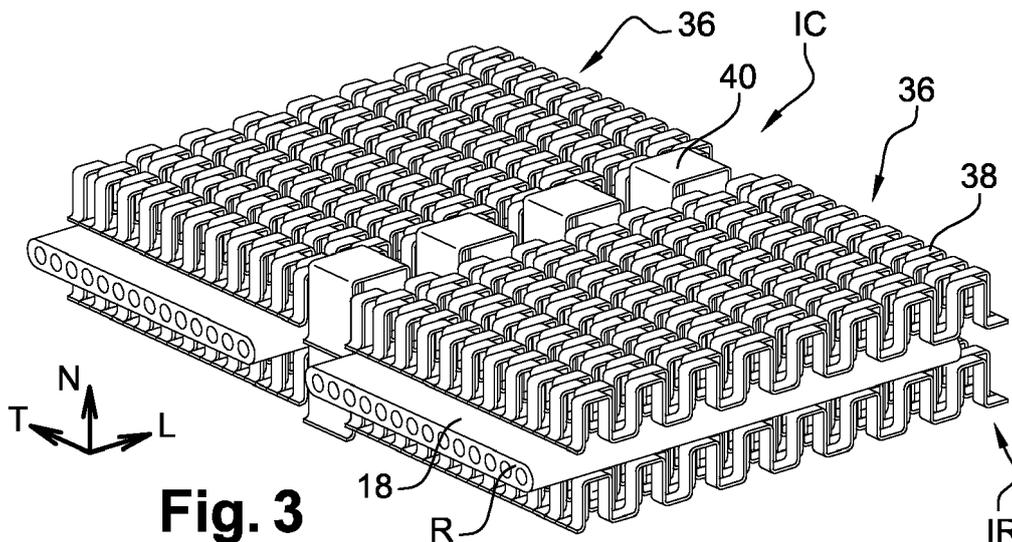
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(54) **Heat exchanger**

(57) A heat exchanger comprises a gas circuit and a coolant circuit enclosed in a container and turbulators (38, 40) arranged in the coolant circuit, between tubes (18), for generating, in use, turbulences of the coolant

flow improving the thermal efficiency of the exchanger. The turbulators (38, 40) are integrally formed in a single turbulators plate (36) extending across a plurality of tubes (18).



**Fig. 3**

## Description

### TECHNICAL FIELD

**[0001]** The present invention relates to heat exchanger for automotive applications.

### BACKGROUND OF THE INVENTION

**[0002]** A heat exchanger, here a gas cooler, of the prior art comprises, enclosed in a container, a gas circuit and a coolant circuit arranged to thermally cooperate so that, gas flowing in longitudinal flat tubes of the gas circuit cools down while coolant circulating between the tubes heats-up.

**[0003]** As can be seen on figure 1, the longitudinal flat tubes are stacked in a rectangular array arrangement of four non-contacting columns and about sixteen non-contacting rows.

**[0004]** To optimize the thermal exchange, turbulators are arranged between the tubes, said turbulators aiming at disturbing the coolant flow forcing it to oscillate in a longitudinal direction. Although the skilled person often identifies said features as turbulators, another more proper designation is offset strip fins. Furthermore the longitudinal flow direction of the coolant is also called the "hard way" while the transversal direction is the "easy way" as the obstacles are not as present as in the hard way.

**[0005]** First turbulators are arranged in the inter-rows space, horizontal space as per the orientation of the figure, in between each two adjacent tubes of a column. Said first turbulators aim at disturbing the coolant flow.

**[0006]** Second turbulators are arranged in the inter-columns space, vertical space as per the orientation of the figure, in between each two adjacent tubes of a row. Said second turbulators aim at preventing the coolant flow to shortcut said oscillating longitudinal path by "dropping" into said vertical space or, simply to prevent said coolant flow to deviate and change inter-rows in the inter-columns space.

**[0007]** In the assembly and manufacturing process, the setting up of the first and second turbulators is delicate as the operators have to vertically stack columns of sandwiches of tubes and first turbulators then, to horizontally stack said sandwiches of columns and second turbulators.

### SUMMARY OF THE INVENTION

**[0008]** Accordingly, it is an object of the present invention to resolve the above mentioned problems in providing a heat exchanger comprising a gas circuit and a coolant circuit enclosed in a container so that, in use, pressurized gas flowing in tubes and liquid coolant flowing between said tubes are in thermal exchange. The heat exchanger further comprises turbulators, arranged in the coolant circuit, between the tubes, for generating, in use, turbulences of the coolant flow improving the thermal ef-

iciency of the exchanger. The turbulators are advantageously integrally formed in a turbulators plate extending across a plurality of tubes.

**[0009]** The turbulators plate integrally comprise first and second sections of turbulators, each comprising periodic pattern corrugations with spatial period along a longitudinal axis and normal peak-to-peak amplitude along a normal axis, perpendicular to said longitudinal axis. The corrugations of the first section have smaller peak-to-peak amplitude than the corrugations of the second sections.

**[0010]** The tubes have a flat cross section and are arranged in a stack of parallel rows, one turbulators plate being arranged in the inter-rows space between adjacent rows of tubes.

**[0011]** More particularly, each tube extends along the longitudinal axis from one longitudinal end of the container to the opposite longitudinal end and, the rows of tubes are arranged on a transverse direction from one lateral end of the container to the opposite lateral end of the container. The turbulators plate extends across the entire area of the inter-rows space, in the longitudinal direction from said one longitudinal end of the container to said opposite longitudinal end and, in the transverse direction from said one lateral end of the container to said opposite lateral end of the container.

**[0012]** The arrangement of tubes is a two dimensional rectangular array comprising a plurality of rows and a plurality of columns.

**[0013]** According to specific embodiments, the heat exchanger comprises at least four columns and at least ten rows.

**[0014]** The columns are non-contacting reserving inter-columns space and wherein the turbulators plates comprise integrally formed first corrugated sections arranged in the inter-rows space and second corrugated sections arranged in the inter-columns spaces. The turbulators plates are arranged in neighbour inter-row spaces and cooperate with each other so that forming a continuous intermediate surface in the inter-columns space between adjacent tubes of the same row. The surface prevent the coolant to flow in the inter-column spaces.

**[0015]** The spatial period pattern of said corrugation is substantially a square wave alternating flat heads portions with flat feet portions.

**[0016]** The peak-to-peak amplitude of the corrugations of the second section can be calculated as:

$$A_{40} = A_{38} + t_{18}$$

where:

$A_{40}$  is the peak-to-peak amplitude of the second section,  
 $A_{38}$  is the peak-to-peak amplitude of the first section and,

t18 is the tube thickness measured along the normal axis.

**[0017]** The first section and the second section are arranged so that the second section extends above the first section by half the tube thickness  $t$  and extends below the first section by half the tube thickness.

**[0018]** The closed container within which are enclosed gas and coolant circuits is provided with a gas inlet and a gas outlet and, with a coolant inlet and a coolant outlet.

**[0019]** More particularly, the heat exchanger here above described, in use, the gas in the gas circuit is pressurized carbon dioxide.

**[0020]** The invention further extends to a method to manufacture a heat exchanger, the method comprising the following steps:

- a) providing flat tubes,
- b) integrally forming corrugated turbulators plates,
- c) stacking (130) a sandwich alternating a turbulators plate (36) and rows (R) of tubes (18), the tubes (18) being pre-positioned and maintained in place by the turbulators, the tubes extending along a longitudinal axis (L) and, the sandwich stack forming a two dimensional array of a plurality of rows (R) and a plurality of columns (C) of tubes.

**[0021]** The method further comprises the steps:

- d) providing a container,
- e) arranging the stack of tubes and turbulators plate in said container,
- f) brazing the assembly.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0022]** The present invention is now described by way of example with reference to the accompanying drawings in which:

Figure 1 is an exploded view of a heat exchanger.  
Figure 2 is a detail of a tabulator plate as per the invention.

Figure 3 is an isometric detail view presenting the arrangement of tubes and turbulators plate of figure 2.

Figure 4 is a side view perpendicular to a longitudinal axis of an arrangement of tubes and turbulators as per the invention

Figure 5 is a section view perpendicular to figure 4 presenting arrangements of turbulators as per the invention.

Figure 6 is a transverse section of the two-dimensional array of the tubes of the heat exchanger as per the invention.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0023]** To ease and clarify the following description the orientation of the figures is arbitrarily chosen and, words and expressions such as "above, under, below, as well as horizontal or vertical..." may be utilized without any intention to limit the invention. Also, similar features full filling similar functions in different embodiments may be identified with same reference numbers.

**[0024]** A heat exchanger, here a liquid cooled gas cooler 10, is sketched on the exploded figure 1. In a tri-axial orthogonal reference system comprising longitudinal axis L, transverse axis, T and, normal axis N, the gas cooler 10 comprises a parallelepiped rectangle container 12 enclosing a gas circuit 14, for a gas to flow in two longitudinal ways L and, a coolant circuit 16 for coolant fluid to flow in oscillating about the longitudinal direction L.

**[0025]** The gas enters the container and flows in the longitudinal direction and, the coolant enters the container 12 and also flows along the longitudinal direction indicated by the large arrow FC. This longitudinal flow direction of the coolant is known to be the "hard way" as, the path followed by the coolant is more tortuous and therefore the speed of the flow is reduced.

**[0026]** In another alternative, the coolant flows along the transversal "easy way", where its flow speed is superior. In the example chosen the coolant flows only one time in the longitudinal direction before exiting the cooler 10. The example of figure 1 is non-limiting as many other arrangements are known, especially gas cooler having another number of tubes arranged in different setting of rows and columns with flow in more than one direction.

**[0027]** Typically, the gas considered is carbon dioxide  $\text{CO}_2$ , also referenced R744 in the standard list of refrigerating fluids and, the coolant is typically a glycol-type fluid.

**[0028]** The gas circuit 14 comprises flat tubes 18 extending along the longitudinal axis L and, in the transverse plan TN perpendicular to said longitudinal axis L, the tubes 18 are stacked in a two dimensional rectangular array, as sketched in figure 6, comprising horizontal rows R and vertical columns C. In said two dimensional array, horizontal spaces identified as inter-rows spaces IR are preserved between adjacent rows R and, vertical spaces identified as inter-columns spaces IC are preserved between adjacent columns C.

**[0029]** The cross section, observed in the transverse plan TN of the flat tubes 18 have two opposite long sides 20 distant from each other by tube thickness  $t_{18}$ , the long sides 20 extending along the transverse axis T and, said long sides 20 being connected at their extremities by two short sides 22, distant from each other by tube width  $w_{18}$ . The short sides 22 can be straight, forming a rectangle cross section, or curved such as in an oblong cross section.

**[0030]** At both their longitudinal extremities, the tubes 18 are sealingly and fluidly connected to manifolds 24 comprising the stack of a header plate, a distributor plate

and of a closing plate, the latter also being a side plate of the container 12. As visible on figure 1, one of the closing plates is provided with inlet 32 and outlet 34 pipes that are integrally formed in said closing plate. Alternative embodiments exist where said inlet and outlet pipes are arranged, for instance, on opposite closing plates.

**[0031]** The coolant flows in between the tubes 18 and, in each inter-rows space IR a large rectangular turbulators plate 36 is arranged. The turbulators are so designated while more formal names are offset, or non-offset, strip fins. Said plate 36 extends across the entire inter-row IR area, longitudinally from one header plate to the opposite header plate and, transversally across all columns C of tubes from one lateral side of the container 12 to the opposite lateral side.

**[0032]** The turbulators plate is now described in reference to figures 2 and 3.

**[0033]** The turbulators plate 36 is a one piece integral plate that comprises longitudinal sections of first turbulators 38 alternating with longitudinal sections of second turbulators 40.

**[0034]** The first turbulators 38 comprise several corrugated strips, each having periodical square-shape pattern with spatial period P38 along the longitudinal axis L and, peak-to-peak amplitude A38 along the normal axis N. Said strips are next to each other, the patterns being longitudinally shifted so that globally, the direct longitudinal direction is obstructed, as better visible on figure 4. This better explains the designation of "hard way" for the current flow along said direction. The turbulators reserve transverse passages, figure 5, forcing the coolant to follow a direction that is globally along said longitudinal axis L but oscillates about the axis L. This oscillated path creates turbulences that improve the thermal exchange compared to a straight laminar flow. Furthermore, said first sections of first turbulators 38 have a transverse width equal to the width w18 of a tube 18.

**[0035]** The sections of second turbulators 40 are narrower as they aim to be arranged in the inter-columns space IC in order to prevent the coolant from deviating in said inter-columns space IC and change inter-rows IR. Such a flow deviation would shortcut the coolant path and would diminish the thermal performance. The second turbulators 40 are also made of a corrugated metal strip that has periodic square-pattern longitudinally L extending. Said square pattern of the second turbulators 40 has a spatial period P40 alternating heads 42 and feet portions 44 and, it also has normal peak-to-peak amplitude A40 with vertical, or normal, legs 46.

**[0036]** As already visible on figures 2 and 3 but now detailed in reference to figures 4 and 5, the first turbulators 38 have heads 42 and feet 44 portions in contact with the flat tubes 18, so the first turbulators have, because of heat transfer performance, a peak-to-peak amplitude A18 equal to the inter-rows normal distance dIR.

**[0037]** The inter-columns space IC is occupied by the second turbulators 40 with head portions 42 normally aligned N and, feet portions 44 also normally aligned N.

In the stack arrangement the second turbulators 40 cooperate and, in the inter-columns IC space an intermediate plan 48 is created alternating heads portion 42 of the turbulators 40 that is below on figure 5 and feet portions 44 of the turbulators 40 that is above in the stack. The peak-to-peak amplitude A40 of the second turbulators 40 is greater than the peak-to-peak amplitude A38 of the first turbulators. It is such that said intermediate plan 48 is positioned on the median symmetrical plan MP of a row R. Furthermore, said intermediate plan 48 is created between each and every adjacent tubes 18 of a row R. Indeed, as best observable on figure 4, the peak-to-peak amplitude A40 of the second turbulators 40 is chosen to normally N extend between two consecutive median plan MP so said amplitude A40 can be simply calculated as the sum of the first turbulators amplitude 38 plus the thickness t18 of the tubes.

$$A40 = A38 + t18$$

**[0038]** Relative to the intermediate plan 38, the second turbulators 40 extend its amplitude A40 above and beyond the amplitude A38 of the first turbulators, by half the thickness, t18 / 2, of a flat tube 18.

**[0039]** Certain steps of the assembly and manufacturing processes 100 of the heat exchanger 10 are now described.

**[0040]** An initial step 110 consists in providing individual components, such as flat tubes 18, turbulators plates 36, manifold 24 and container's side plates.

**[0041]** A subsequent step 120 consists in stacking a sandwich alternating a turbulators plate 36 and a row R of flat tubes 18. In the example of figure 1, this stacking step 120 would consist in arranging a turbulators plate 36 on a level surface and arranging a flat tube 18 in each of the first sections of first turbulators 38. As the width of a first section is equal to the width w18 of a tube 18, the turbulators plates 36 enable to pre-position and maintain in place the flat tubes 18. Said step 120 is repeated until the number of rows is made.

**[0042]** Advantageously, the integral turbulators plate 36 ease the stacking as each tube 18 is pre-positioned in a first section 38 and is maintained apart from its neighbor tube 18 by a second section 40.

**[0043]** When the stack is completed, the following steps consist in connecting the manifolds 24, enclosing the stack in the container plates and joining the assembly, for instance with a brazing operation.

**[0044]** The following references have been utilized in this description:

10	heat exchanger - gas cooler
12	container
14	gas circuit
16	coolant circuit
18	flat tubes

20	long side of the cross section of the flat tube
22	short side of the cross section of the flat tube
24	manifold
32	gas inlet pipes
34	gas outlet pipes
36	turbulator plate
38	first turbulators
40	second turbulators
42	head portion
44	foot portion
46	leg of turbulators
48	intermediate plan
50	height
52	coolant inlet pipes
54	coolant outlet pipes
100	Assembly and manufacturing method
110	providing step
120	forming turbulators plate
130	stacking step
L	longitudinal axis
N	normal axis
T	transverse axis
R	rows of tubes
C	columns of tubes
IR	inter-rows
IC	inter-columns
P38	spatial period of the first turbulators
A38	peak-to-peak amplitude of the first turbulators
P40	spatial period of the second turbulators
A40	peak-to-peak amplitude of the second turbulators
MP	median plan of a row of tube
TN	plan perpendicular to the longitudinal axis
t18	thickness of a flat tube
w18	width of flat tube
FC	coolant flow direction

## Claims

- Heat exchanger (10) comprising a gas circuit (14) and a coolant circuit (16) enclosed in a container (12) so that, in use, pressurized gas flowing in tubes (18) and liquid coolant flowing between said tubes (18) are in thermal exchange, the heat exchanger (10) further comprising turbulators (38, 40) arranged in the coolant circuit (16), between the tubes (18), for generating, in use, turbulences of the coolant flow improving the thermal efficiency of the exchanger (10), **characterized in that** the turbulators (38, 40) are integrally formed in a turbulators plate (36) extending across a plurality of tubes (18).
- Heat exchangers (10) as set in the preceding claim wherein the turbulators plate (36) integrally comprise first (38) and second (40) sections of turbulators, each comprising periodic pattern corrugations with spatial period (P38, P40) along a longitudinal axis (L) and normal peak-to-peak amplitude (A38, A40) along a normal axis (N), perpendicular to said longitudinal axis (L), the corrugations of the first section (38) having smaller peak-to-peak amplitude (A38) than the corrugations of the second sections (40), said turbulators also being identified as offset strip fins.
- Heat exchanger (10) as set in claim 2 wherein the tubes (18) have a flat cross section and are arranged in a stack of parallel rows (R), one turbulators plate (36) being arranged in the inter-rows space (IR) between adjacent rows (R) of tubes (18).
- Heat exchanger (10) as set in claim 3 wherein each tube (18) extends along the longitudinal axis (L) from one longitudinal end of the container to the opposite longitudinal end and, the rows (R) of tubes (18) are arranged on a transverse direction (T) from one lateral end of the container (12) to the opposite lateral end of the container, the turbulators plate (36) extending across the entire area of the inter-rows space (IR), in the longitudinal direction (L) from said one longitudinal end of the container (12) to said opposite longitudinal end and, in the transverse direction (T) from said one lateral end of the container (12) to said opposite lateral end of the container (12).
- Heat exchanger (10) as set in claim 4 wherein the arrangement of tubes (18) is a two dimensional rectangular array comprising a plurality of rows (R) and a plurality of columns (C).
- Heat exchanger (10) as set in claim 5 comprising at least four columns (C) and at least ten rows (R).
- Heat exchanger (10) as set in any of the claims 5 or 6 wherein the columns (C) are non-contacting reserving inter-columns (IC) space and wherein the turbulators plates (36) comprise integrally formed first corrugated sections (38) arranged in the inter-rows (IR) space and second corrugated sections (40) arranged in the inter-columns (IC) spaces.
- Heat exchanger (10) as set in claim 7 wherein turbulators plates (36) arranged in neighbour inter-row (IR) spaces cooperate with each other so that forming a continuous intermediate surface (48) in the inter-columns (IC) space between adjacent tubes (18) of the same row (R), said surface (48) preventing the coolant to flow in the inter-column spaces.
- Heat exchanger (10) as set in claim 8 wherein the spatial period (P38, P40) pattern of said corrugation is substantially a square wave alternating flat heads portions (42) with flat feet portions (44).

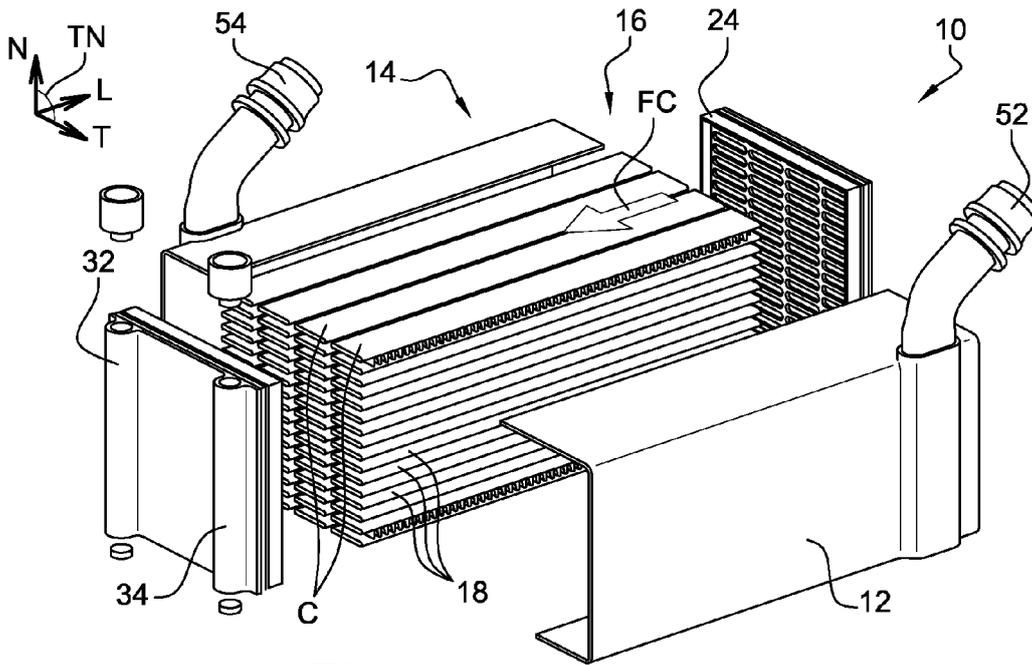
10. Heat exchanger (10) as set in claim 9 wherein the peak-to-peak amplitude (A40) of the corrugations of the second section (40) can be calculated as:

$$A40 = A38 + t18$$

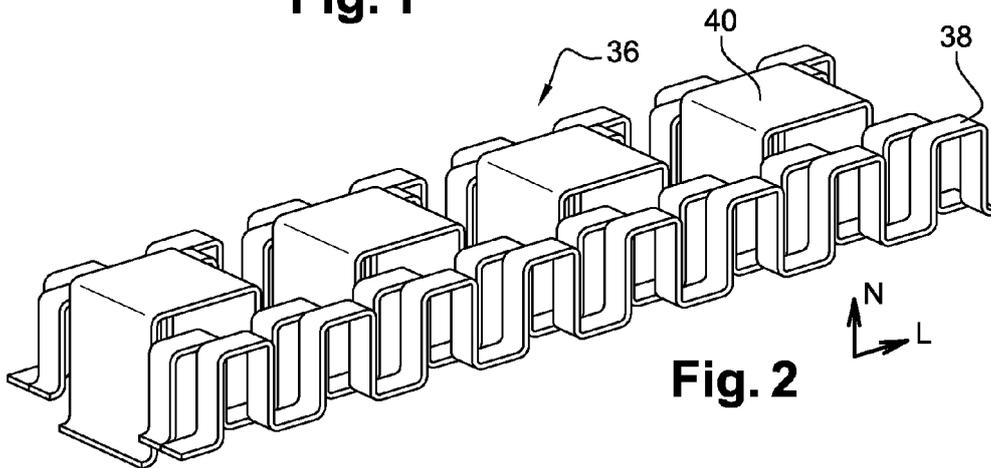
where:

A40 is the peak-to-peak amplitude of the second section,  
 A38 is the peak-to-peak amplitude of the first section and,  
 t18 is the tube thickness measured along the normal axis.

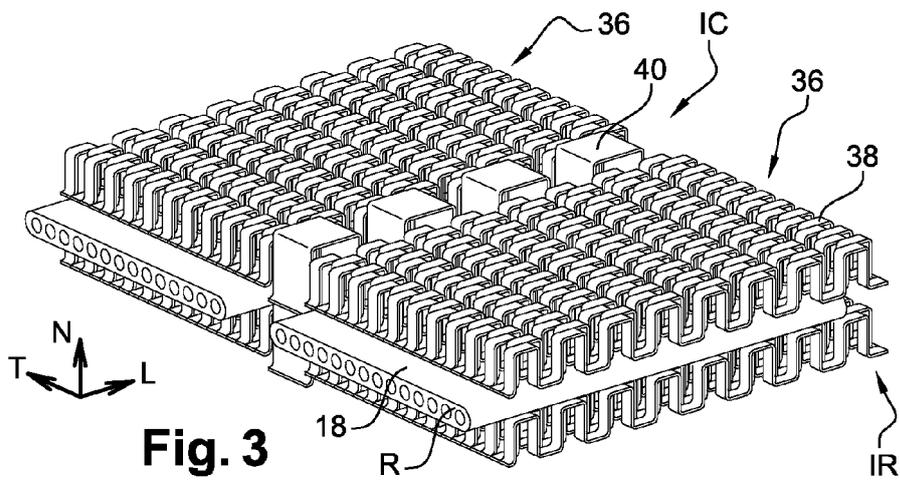
11. Heat exchanger (10) as set in claim 10 wherein the first section (38) and the second section (40) are arranged so that the second section (40) extends above the first section (38) by half the tube thickness (t18) and extends below the first section by half the tube thickness (t18).
12. Heat exchanger (10) as set in any one of the preceding claims wherein the closed container (12) within which are enclosed gas and coolant circuits is provided with a gas inlet (32) and a gas outlet (34) and with, a coolant inlet (52) and a coolant outlet (54).
13. Heat exchanger (10) as set in any one of the preceding claims wherein, in use, the gas in the gas circuit (14) is pressurized carbon dioxide (CO<sub>2</sub>, R744).
14. Method (100) to manufacture a heat exchanger, the method comprising the following steps:
- a) providing (110) flat tubes (18),
  - b) integrally forming (120) corrugated turbulators plates (36),
  - c) stacking (130) a sandwich alternating a turbulators plate (36) and rows (R) of tubes (18), the tubes (18) being pre-positioned and maintained in place by the turbulators, the tubes extending along a longitudinal axis (L) and, the sandwich stack forming a two dimensional array of a plurality of rows (R) and a plurality of columns (C) of tubes.
15. Method (100) as set in claim 14 further comprising the steps:
- d) providing a container,
  - e) arranging the stack of tubes and turbulators plate in said container,
  - f) brazing the assembly.



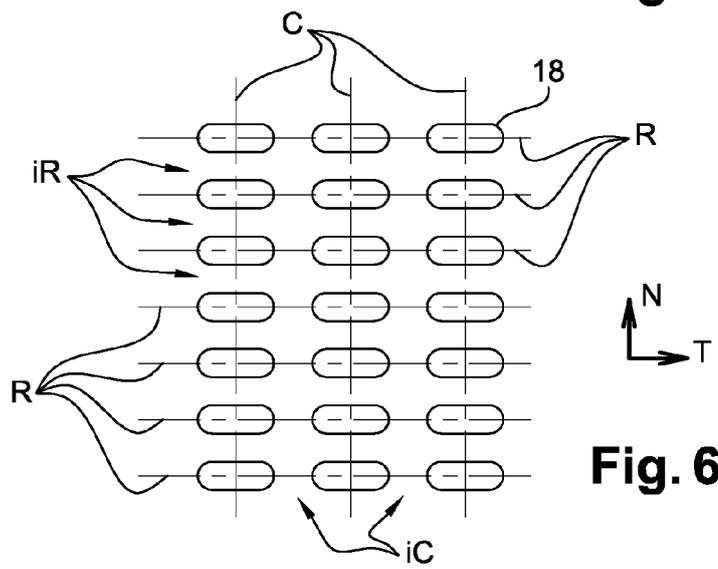
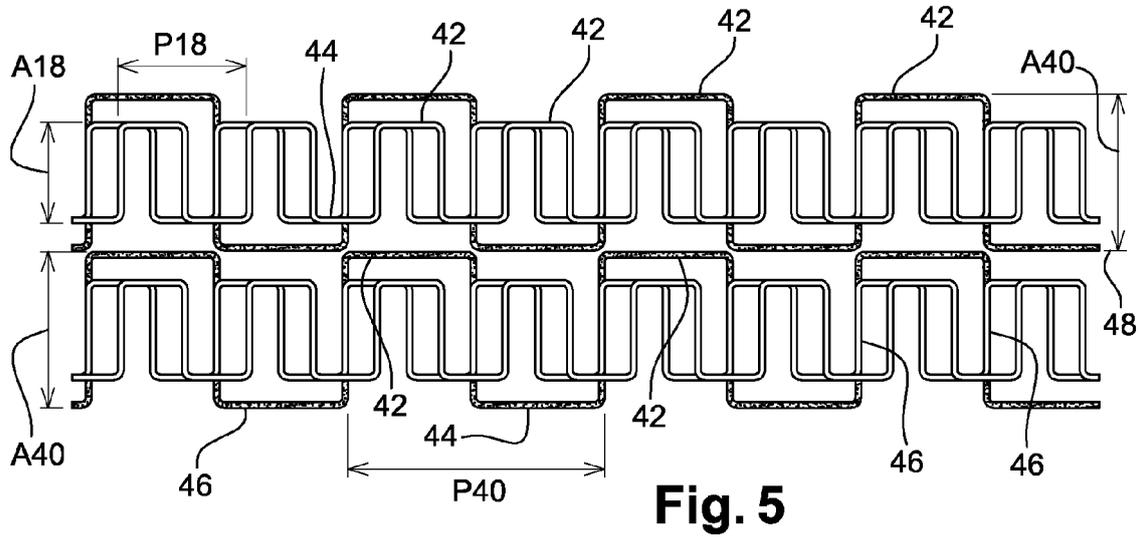
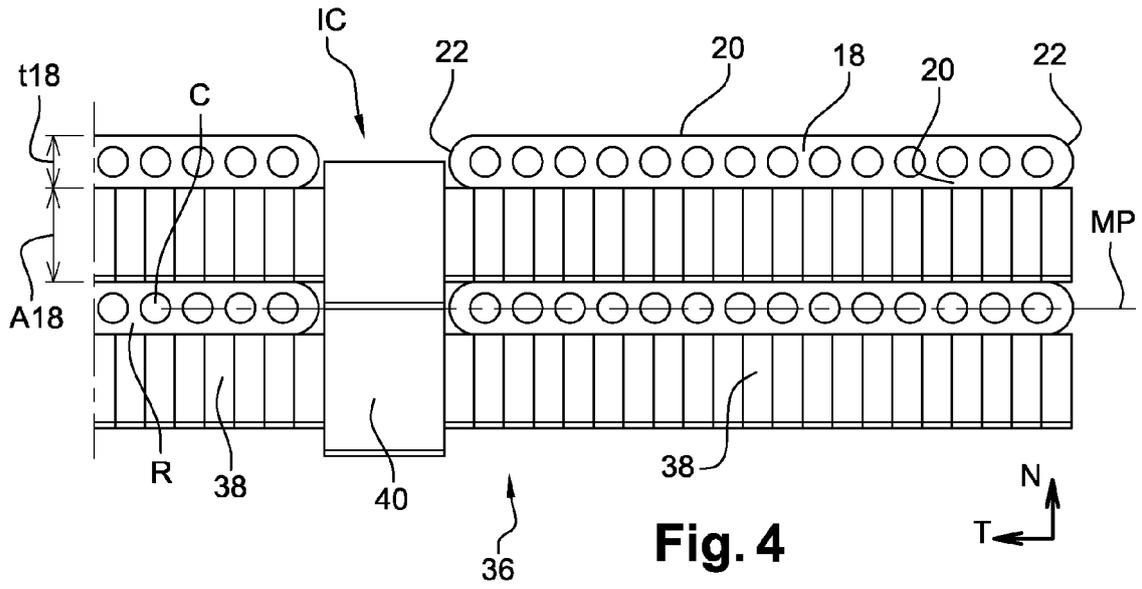
**Fig. 1**



**Fig. 2**



**Fig. 3**





EUROPEAN SEARCH REPORT

Application Number  
EP 14 17 6288

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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 10 2012 224353 A1 (BEHR GMBH & CO KG [DE]) 26 June 2014 (2014-06-26)	1	INV. F28D7/16 F28F1/28 F28F13/12 F28D21/00
A	* paragraphs [0052] - [0057]; figures 3-5 *	2-15	
A	DE 10 2006 046061 A1 (SHOWA DENKO KABUSHIKI KAISHA D [JP]) 19 April 2007 (2007-04-19) * the whole document *	1-15	
A	US 2003/010488 A1 (WATANABE TOSHIHARU [JP] ET AL) 16 January 2003 (2003-01-16) * the whole document *	1-15	
A	US 2003/106677 A1 (MEMORY STEPHEN [US] ET AL) 12 June 2003 (2003-06-12) * the whole document *	1-15	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			F28D F28F
Place of search		Date of completion of the search	Examiner
Munich		23 September 2014	Axters, Michael
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons	
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**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 14 17 6288

5

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102012224353 A1	26-06-2014	DE 102012224353 A1 WO 2014095594 A1	26-06-2014 26-06-2014
DE 102006046061 A1	19-04-2007	DE 102006046061 A1 JP 2007093025 A	19-04-2007 12-04-2007
US 2003010488 A1	16-01-2003	DE 10231645 A1 FR 2827224 A1 JP 2003097857 A US 2003010488 A1 US 2006005941 A1 US 2006254748 A1	30-01-2003 17-01-2003 03-04-2003 16-01-2003 12-01-2006 16-11-2006
US 2003106677 A1	12-06-2003	AR 037710 A1 AU 2002343716 A1 BR 0213723 A CA 2464686 A1 CN 1650143 A DE 02780677 T1 EP 1459028 A1 JP 3965387 B2 JP 2005512013 A KR 20040063966 A MX PA04004922 A RU 2287755 C2 US 2003106677 A1 WO 03050468 A1 ZA 200403169 A	01-12-2004 23-06-2003 26-10-2004 19-06-2003 03-08-2005 23-06-2005 22-09-2004 29-08-2007 28-04-2005 15-07-2004 11-08-2004 20-11-2006 12-06-2003 19-06-2003 22-02-2006

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