(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 730 891 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
28.10.2020 Bulletin 2020/44

(51) Int Cl.:
F28F 3/02 *(2006.01)* ***F28F 13/08*** *(2006.01)*
F28F 13/02 *(2006.01)* ***F28F 3/04*** *(2006.01)*

(21) Application number: **19212330.5**

(22) Date of filing: **28.11.2019**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **26.04.2019 US 201916396124**

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(54) HEAT EXCHANGER FOR HIGH PRANDTL NUMBER FLUIDS

(57) A fluid heat exchanger including a channel (108) for passing a first fluid therethrough arranged along a primary axis including at least two segments of a first flow pattern, wherein a length of at least one segment being set in relation to a hydraulic diameter and a Prandtl number of the first fluid, and a first pattern flow disruptor (116) interspersed between each of the segments of the first flow pattern configured to reduce a pressure loss of the fluid flow along the channel.

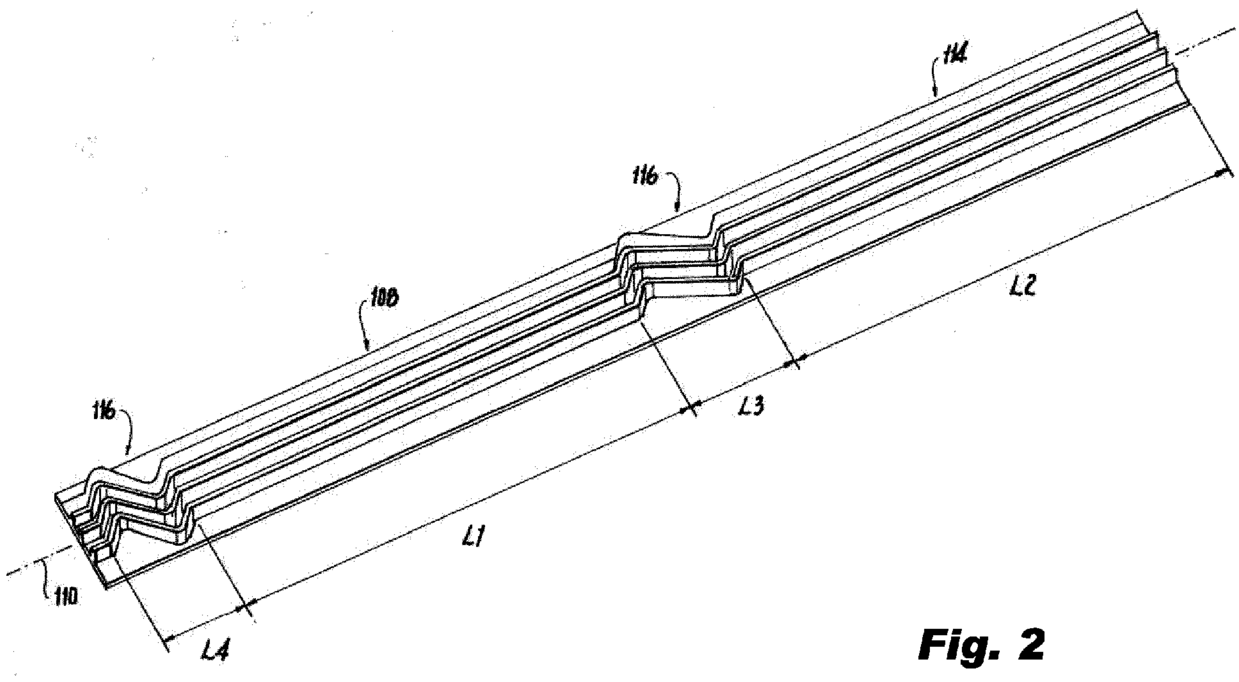

Fig. 2

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Description

Background

Technological Field

[0001] The present disclosure relates to a heat exchanger, and more particularly to a heat exchanger for a high Prandtl number fluid.

Description of Related Art

[0002] A variety of devices are known in the heat exchanger area. However High-Viscosity/Prandtl-number fluids such as oils or glycol solutions result in poor heat transfer and high pressure drop. Surface augmentations are often used to enhance heat transfer; however, result in even higher pressure drop.

[0003] The conventional methods and systems have generally been considered satisfactory for their intended purpose. However, there is still a need in the art for heat exchanger having improved heat transfer capabilities. There also remains a need in the art for such heat exchangers and components that are economically viable. The present disclosure may provide a solution for at least one of these remaining challenges.

Summary of the Invention

[0004] A fluid heat exchanger includes a channel for passing a first fluid therethrough arranged along a primary axis including at least two segments of a first flow pattern, wherein at least one segment of the at least two segments defines a length greater than five times a hydraulic diameter of the channel, and a first pattern flow disruptor interspersed between each of the segments of the first flow pattern configured to reduce a pressure loss of the fluid flow along the channel, and a second series of channels for passing a second fluid therethrough for transferring energy to the first fluid. A first segment of the at least two segments can define a length different from a length of a second segment of the at least two segments. The length of the first segment can be defined by the equation $5D_h < L < 4D_hP_r$ wherein L is the length of the first segment, D_h is the hydraulic diameter of the first segment, and Pr is the expected steady state Prandtl number of the first fluid at a location along the first segment. The length of the second segment can be defined by the equation $5D_h < L < 4D_hPr$ wherein L is the length of the second segment, D_h is the hydraulic diameter of the second segment, and Pr is the expected steady state Prandtl number of the first fluid at a location along the second segment.

[0005] The segments of the first flow pattern can be aligned in the same direction. The segments of the first flow pattern can be straight. The first pattern flow disruptor can narrow the flow channel. The first pattern flow disruptor can change a direction of flow of the first fluid. The first pattern flow disruptor can include multiple disruptors, wherein at least one of the flow disruptors includes a longer length than another disruptor.

[0006] A method of transferring heat between fluids includes directing a fluid through a heat exchanger channel and developing a thermal boundary layer between the fluid and a surface of the channel and a momentum boundary layer between the fluid and the surface of the channel, wherein the thermal boundary layer of the fluid includes a different thickness than a thickness of the momentum boundary layer, and directing a second fluid through a second channel adjacent to the first channel and transferring heat from the first fluid to the second fluid.

[0007] The fluid includes a Pradntl number greater than 1, or preferably a Prandtl number greater than 7. The thermal boundary layer of the fluid is thinner than the momentum boundary layer. A ratio of thermal boundary thickness to momentum boundary layer thickness can decrease along a flow direction of the fluid and the ratio of thermal boundary thickness to momentum boundary layer thickness can be greater than 1.

[0008] These and other features of the systems and methods of the subject disclosure will become more readily apparent to those skilled in the art from the following detailed description of the preferred embodiments taken in conjunction with the drawings.

Brief Description of the Drawings

[0009] So that those skilled in the art to which the subject invention appertains will readily understand how to make and use the devices and methods of the subject invention without undue experimentation, preferred embodiments thereof will be described in detail herein below with reference to certain figures, wherein:

Fig. 1 is a perspective view of a heat exchanger;

Fig. 2 is a perspective view of a heat exchanger plane of Fig. 1, showing a channel for transporting a fluid;

Fig. 3 is a perspective view of an alternate embodiment of Fig. 1, showing a second type of flow disruptor; and

Fig. 4 is a perspective view of an alternate embodiment of Fig. 1, showing a third type of flow disruptor.

Detailed Description

[0010] Reference will now be made to the drawings wherein like reference numerals identify similar structural features or aspects of the subject invention. For purposes of explanation and illustration, and not limitation, a partial view of an exemplary embodiment of a heat exchanger channel in accordance with the invention is shown in Fig. 1 and is designated generally by reference character 100. Other embodiments of heat exchanger channel in accordance with the invention, or aspects thereof, are provided in Figs. 2-4, as will be described. The methods and systems of the invention can be used to improve heat transfer using fluids with a high Prandtl number.

[0011] Referring to Fig. 1, a heat exchanger 100 having multiple channels for passing fluids therethough is shown. The heat exchanger 100 includes a hot fluid inlet 102, a cold fluid inlet 104, and a header 106. The disclosure focuses on the structure of the individual channels for the hot fluid and the cold fluid.

[0012] Referring to Figs. 2-4, a channel 108 for passing a first fluid therethrough is arranged along a primary axis 110 including at least two segments 112, 114 of a first flow pattern. A first segment 112 defines a length L1 that may be different from a length L2 of a second segment 114, and a first pattern flow disruptor 116 is interspersed between each of the segments of the first flow pattern to enhance heat transfer of the fluid flow along the channel 108. The channel 108 can include multiple segments of the first flow pattern, and multiple disruptors 116. The length of the first segment L1 is defined by the equation $5D_h < L1 < 4D_hPr$ wherein $L1$ is the length of the first segment, D_h is the hydraulic diameter of the first segment, and Pr is the expected steady state Prandtl number of the first fluid at a location along the first segment 112, and the length of the second segment is defined by the equation $5D_h < L2 < 4D_hPr$ wherein $L2$ is the length of the second segment, D_h is the hydraulic diameter of the second segment, and Pr is the expected steady state Prandtl number of the first fluid at a location along the second segment 114. The Prandtl number can be calculated at the midpoint of each segment. However, an average Prandtl number can be used, as the number is not expected to vary substantially within each segment. The Prandtl number is a dimensionless number defined as the ratio of momentum diffusivity to thermal diffusivity. Wherein the momentum diffusion rate is dependent of the dynamic viscosity and density of the fluid along a heat exchange channel, and the thermal diffusivity is dependent of the thermal conductivity and density of the fluid, which again varies along the flow path. Using an expected steady state Prandtl number of fluid flowing through a heat exchanger, the heat exchanger channel is sized accordingly.

[0013] The segments 112, 114 of the first flow pattern are aligned in the same direction. The segments 112, 114 of the first flow pattern can be straight. As shown in Fig. 2, the flow disruptor 116 can be a sinusoidal path attached to the straight first flow pattern. As shown in Fig. 3, the flow disruptor 116 can be straight flow and set-off from the first flow pattern. As shown in Fig. 4, the first pattern flow disruptor 116 can narrow the flow channel or change a direction of flow of the first fluid. It is further contemplated that the first pattern flow disruptor 116 can include multiple disruptors between each of the first flow pattern portions 112, 114. The disruptors can be of various shapes and sizes. The disruptors can include various lengths along the same path, which can be beneficial for channels for larger changes in Pr.

[0014] A method of transferring heat between fluids using a heat exchanger is also disclosed. The method includes directing a first fluid through a heat exchanger channel and developing a thermal boundary layer between the first fluid and a surface of the channel and a momentum boundary layer between the first fluid and the surface of the channel, wherein the thermal boundary layer of the first fluid includes a different thickness than a thickness of the momentum boundary layer. Directing a second fluid through a second channel adjacent to the first channel and transferring heat from the first fluid to the second fluid. The first fluid includes a Pradntl number greater than 1, or more specifically a Prandtl number greater than 7.

[0015] For fluids with a Prandtl number above 1, the thermal boundary layer of the first fluid is thinner than the momentum boundary layer. A ratio of thermal boundary thickness to momentum boundary layer thickness decreases along with the flow of the fluid and the ratio is always greater than 1.

[0016] The method described above is leveraged to augment heat transfer while reducing pressure drop penalty by intermittently disturbing the flow at desired intervals, where the momentum profile is allowed to recover while the thermal profile remains augmented. For fluids having a high Prandtl number the flow through the first segement (L1) result in lower pressure drop with little degradation to the enhancement in heat transfer caused by the disruptor. The optimal length the disruptors can be selected based on expected steady state conditions and fluid properties. The implementation of this method has shown an improvement of approximately 30% more heat transfer with respect to conventional methods, while keeping the pressure drop penalty unchanged.

[0017] The methods and systems of the present disclosure, as described above and shown in the drawings, provide for a heat exchanger with superior properties heat transfer. While the apparatus and methods of the subject disclosure have been showing and described with reference to embodiments, those skilled in the art will readily appreciate that changes and/or modifications may be made thereto without departing from the scope of the subject disclosure.

Claims

1. A fluid heat exchanger comprising:

a channel (108) for passing a first fluid therethrough arranged along a primary axis including at least two segments of a first flow pattern, wherein a length of at least one segment being set in relation to a hydraulic diameter and a Prandtl number of the first fluid; and

a first pattern flow disruptor (116) interspersed between each of the segments of the first flow pattern configured to reduce a pressure loss of the fluid flow along the channel.

2. The heat exchanger of claim 1, wherein at least one segment of the at least two segments defines a length greater than five times a hydraulic diameter of the channel.

3. The heat exchanger of claims 1 or 2, wherein a first segment of the at least two segments defines a length different from a length of a second segment of the at least two segments.

4. The heat exchanger of claim 3, wherein the length of the first segment is defined by the equation $5D_h < L < 4D_hPr$ wherein L is the length of the first segment, D_h is the hydraulic diameter of the first segment, and Pr is the expected steady state Prandtl number of the first fluid at a location along the first segment; and/or wherein the length of the second segment is defined by the equation $5D_h < L < 4D_hPr$ wherein L is the length of the second segment, D_h is the hydraulic diameter of the second segment, and Pr is the expected steady state Prandtl number of the first fluid at a location along the second segment.

5. The heat exchanger of any preceding claim, wherein the segments of the first flow pattern are aligned in the same direction, and/or wherein the segments of the first flow pattern are straight.

6. The heat exchanger of claim 1, wherein the first pattern flow disruptor narrows the flow channel.

7. The heat exchanger of any preceding claim, wherein the first pattern flow disruptor changes a direction of flow of the first fluid.

8. The heat exchanger of any preceding claim, wherein the first pattern flow disruptor includes multiple disruptors, and preferably wherein at least one of the flow disruptors includes a longer length than another disruptor.

9. The heat exchanger of any preceding claim, further comprising a second series of channels for passing a second fluid therethrough for transferring energy to the first fluid.

10. A method of transferring heat between fluids comprising:

directing a fluid through a heat exchanger channel; and
developing a thermal boundary layer between the fluid and a surface of the channel and a momentum boundary layer between the fluid and the surface of the channel, wherein the thermal boundary layer of the fluid includes a different thickness than a thickness of the momentum boundary layer.

11. The method of claim 10, wherein the fluid includes a Pradntl number greater than 1.

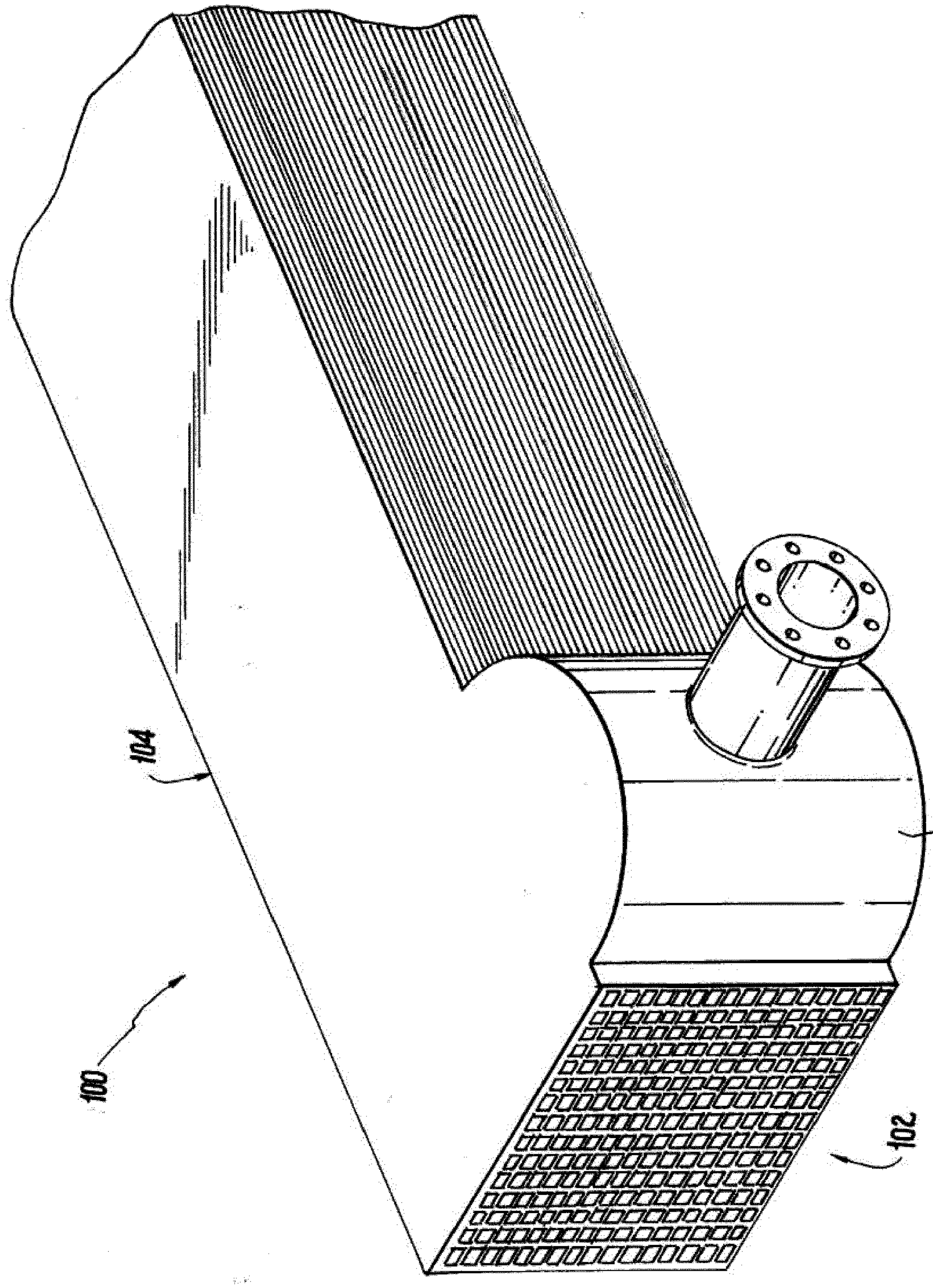
12. The method of claims 10 or 11, wherein the fluid includes a Prandtl number greater than 7.

13. The method of any of claims 10 to 12, wherein the thermal boundary layer of the fluid is thinner than the momentum boundary layer.

14. The method of any of claims 10 to 13, wherein a ratio of thermal boundary thickness to momentum boundary layer thickness decreases along a flow direction of the fluid, and preferably wherein the ratio of thermal boundary thickness to momentum boundary layer thickness is greater than 1.

15. The method of any of claims 10 to 14, further comprising directing a second fluid through a second channel adjacent to the first channel and transferring heat from the first fluid to the second fluid.

Fig. 1



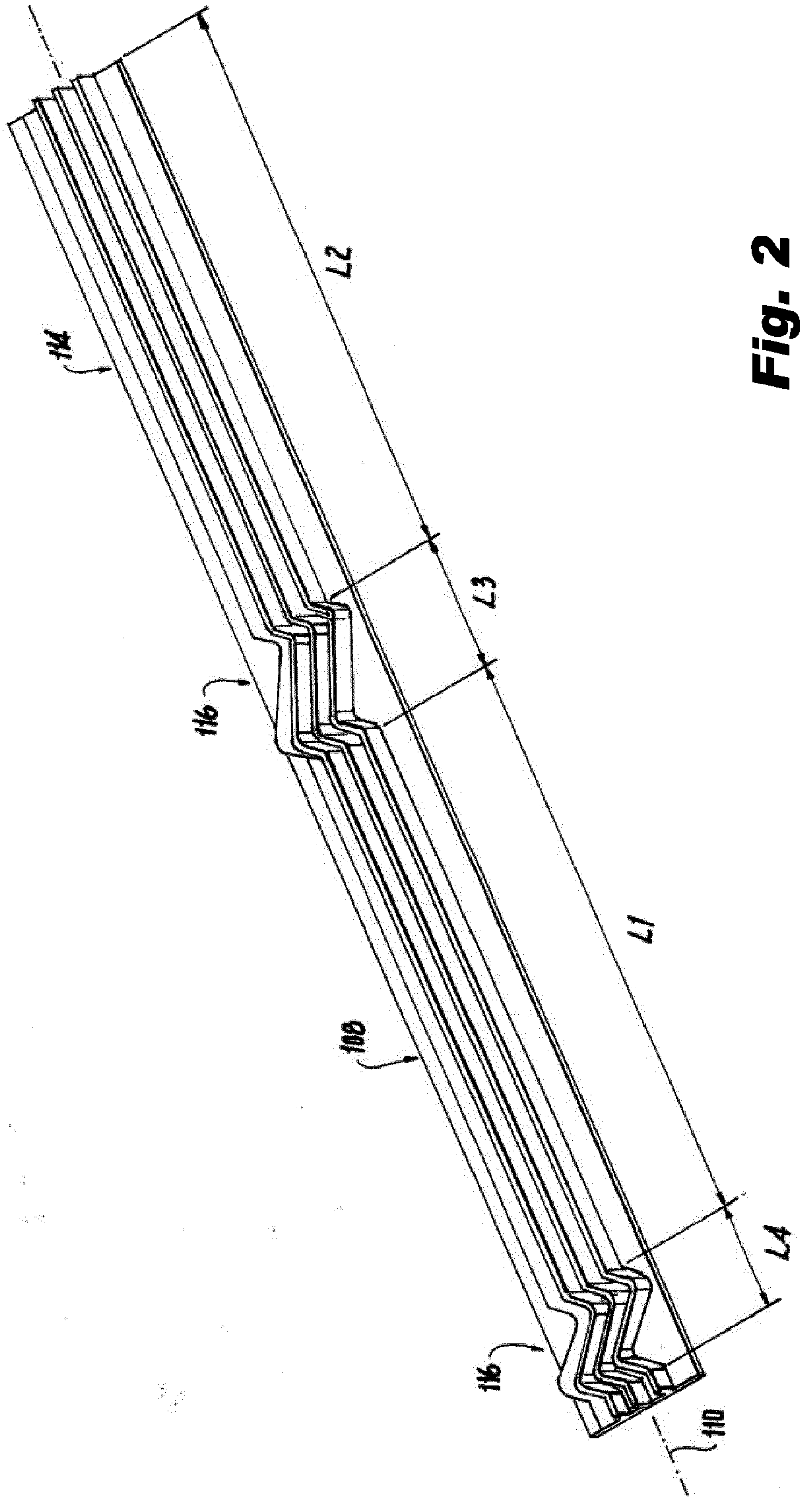


Fig. 2

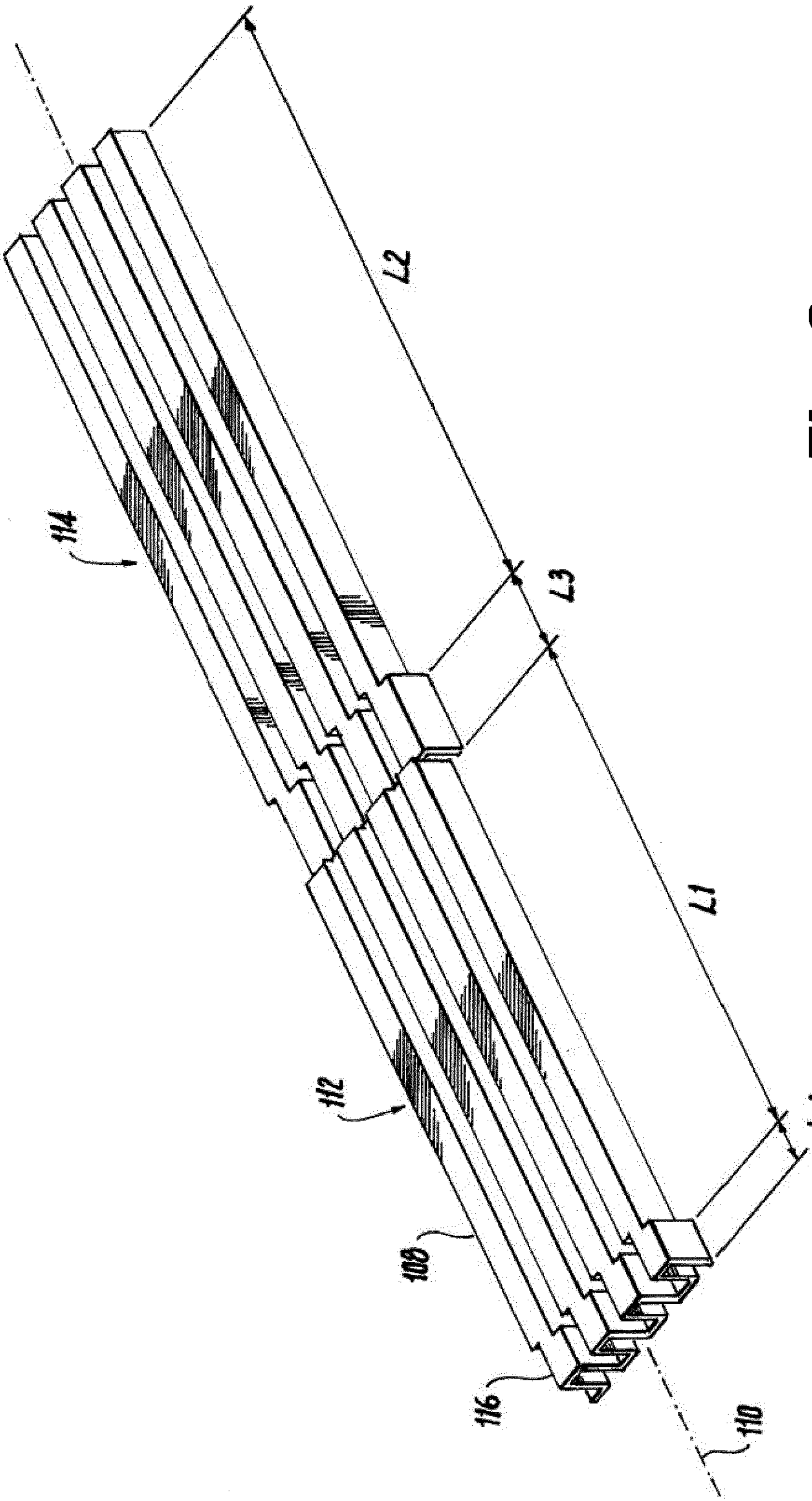


Fig. 3

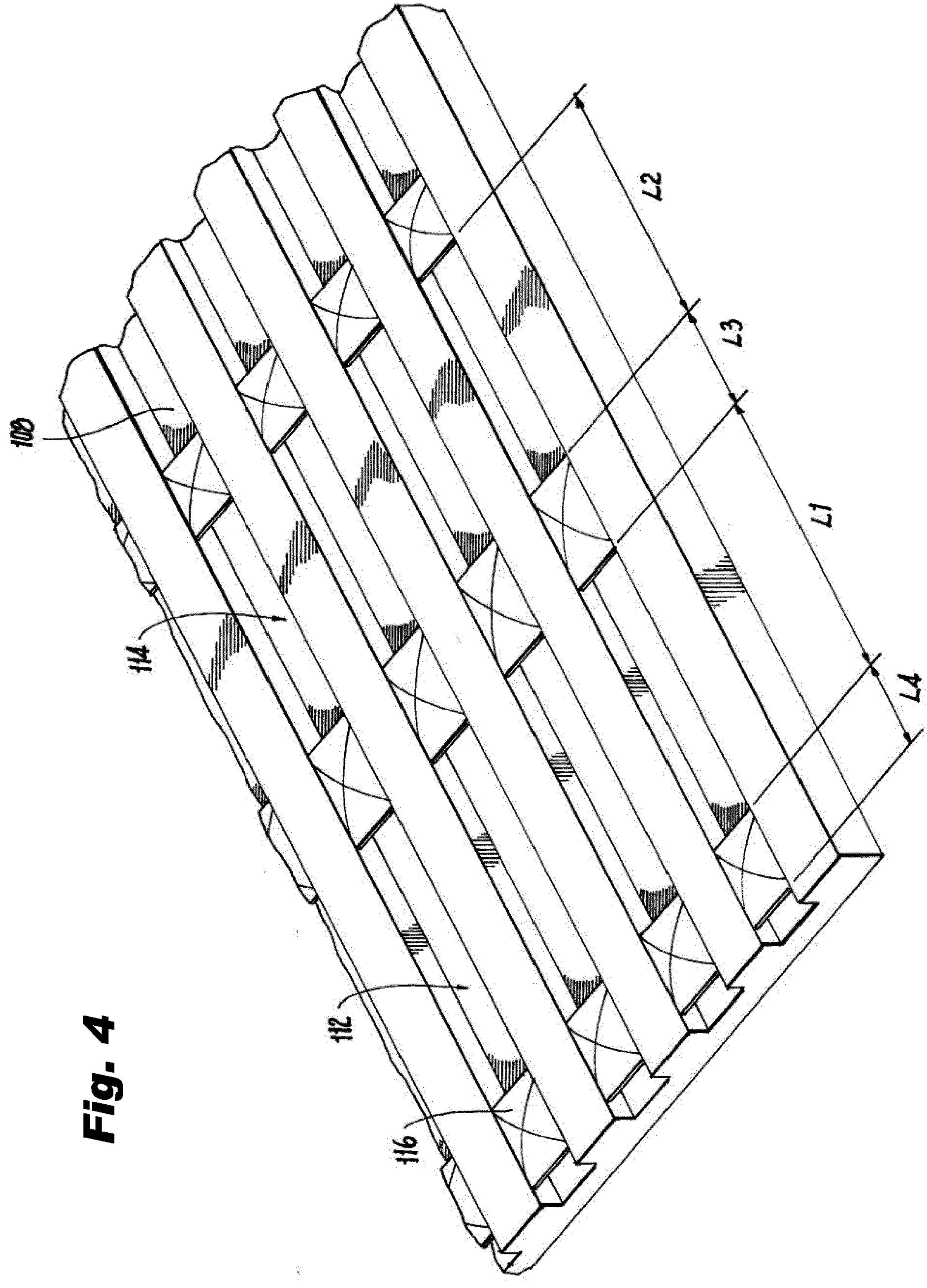


Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 19 21 2330

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	CA 2 290 230 A1 (PAUL EBERHARD [DE]) 20 May 2000 (2000-05-20) * figures 2-6 * -----	1-9	INV. F28F3/02 F28F13/08 F28F13/02 F28F3/04
X	US 2016/327346 A1 (DZIUBINSCHI OREST ALEXANDRU [US] ET AL) 10 November 2016 (2016-11-10) * figure 2 * -----	1	
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X	US 3 111 982 A (KURT ULBRICHT) 26 November 1963 (1963-11-26) * figure 3a * -----	1	

TECHNICAL FIELDS SEARCHED (IPC)

F28F
F28D

2

~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
Munich	15 June 2020	Martínez Rico, Celia

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

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
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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Application Number
EP 19 21 2330

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-9

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 19 21 2330

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-9

Heat exchanger comprising a channel with two segments for a first pattern flow and a disruptor between the two segments.

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2. claims: 10-15

Method for transferring heat between fluids developing a thermal boundary layer and a momentum boundary layer between the fluid and the surface of the channel, the layers having a different thickness.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 19 21 2330

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
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15-06-2020

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