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(54) HEAT EXCHANGER

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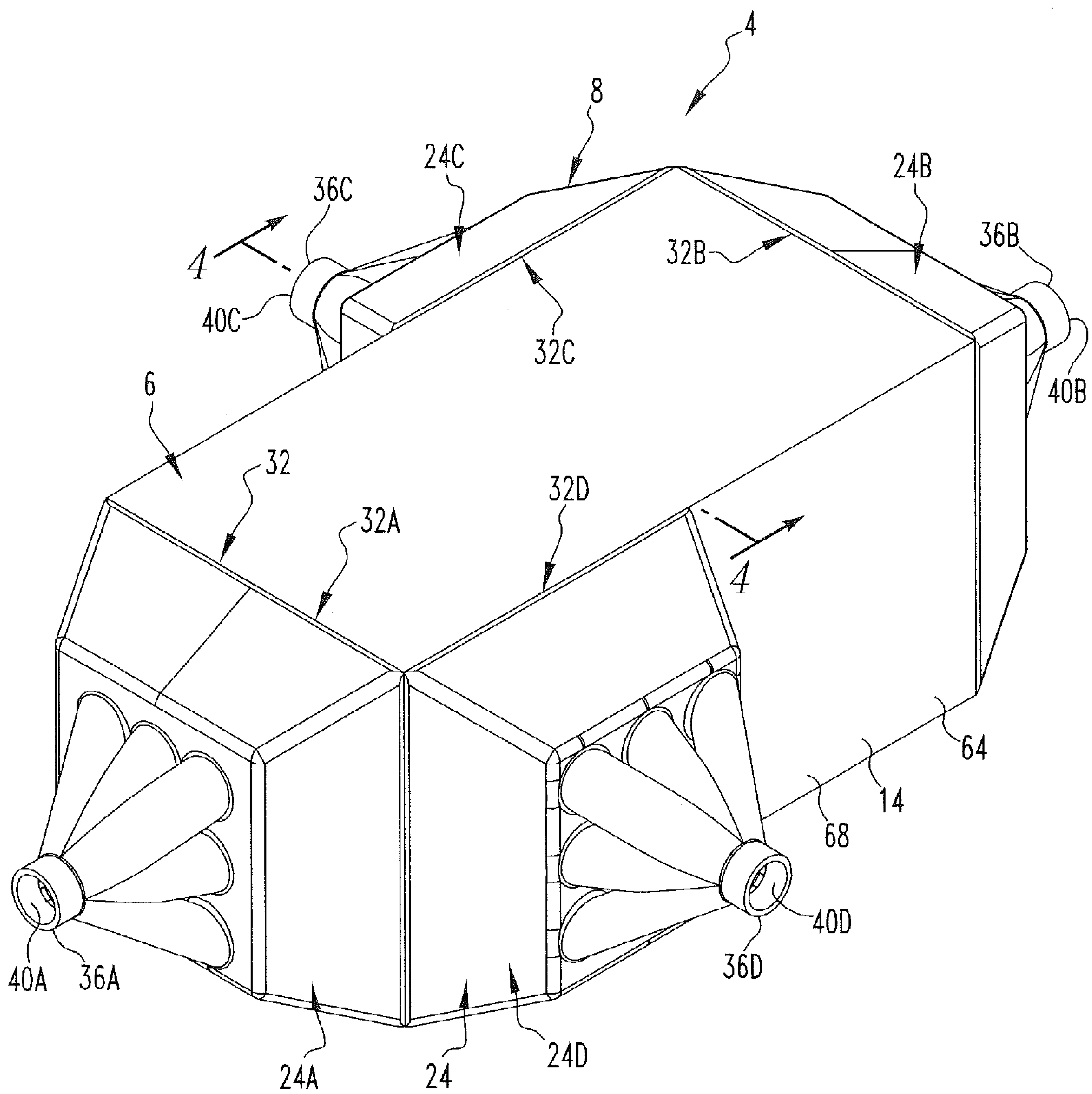
(57) ABSTRACT

A compact heat exchanger is formed from a plurality of very thin layers that are affixed to one another and that are formed via additive manufacturing. Such additive manufacturing enables the configurations of the heat exchanger's flow channels and the arrangements of such flow channels to be optimized for improved heat transfer performance, for improved resistance to thermal and mechanical stresses, and for optimization based upon other factors such as the environment in which the heat exchanger will be situated.



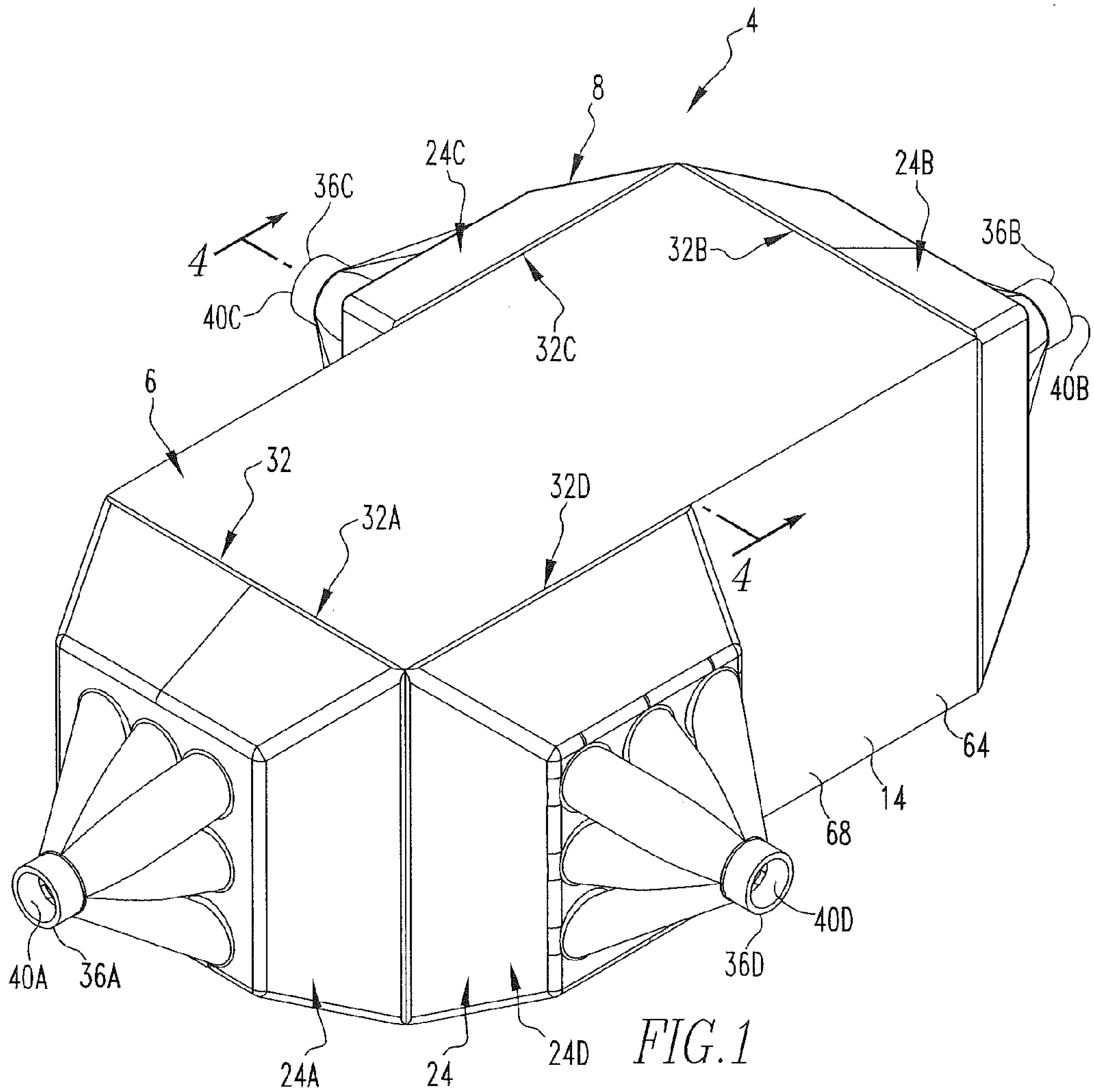
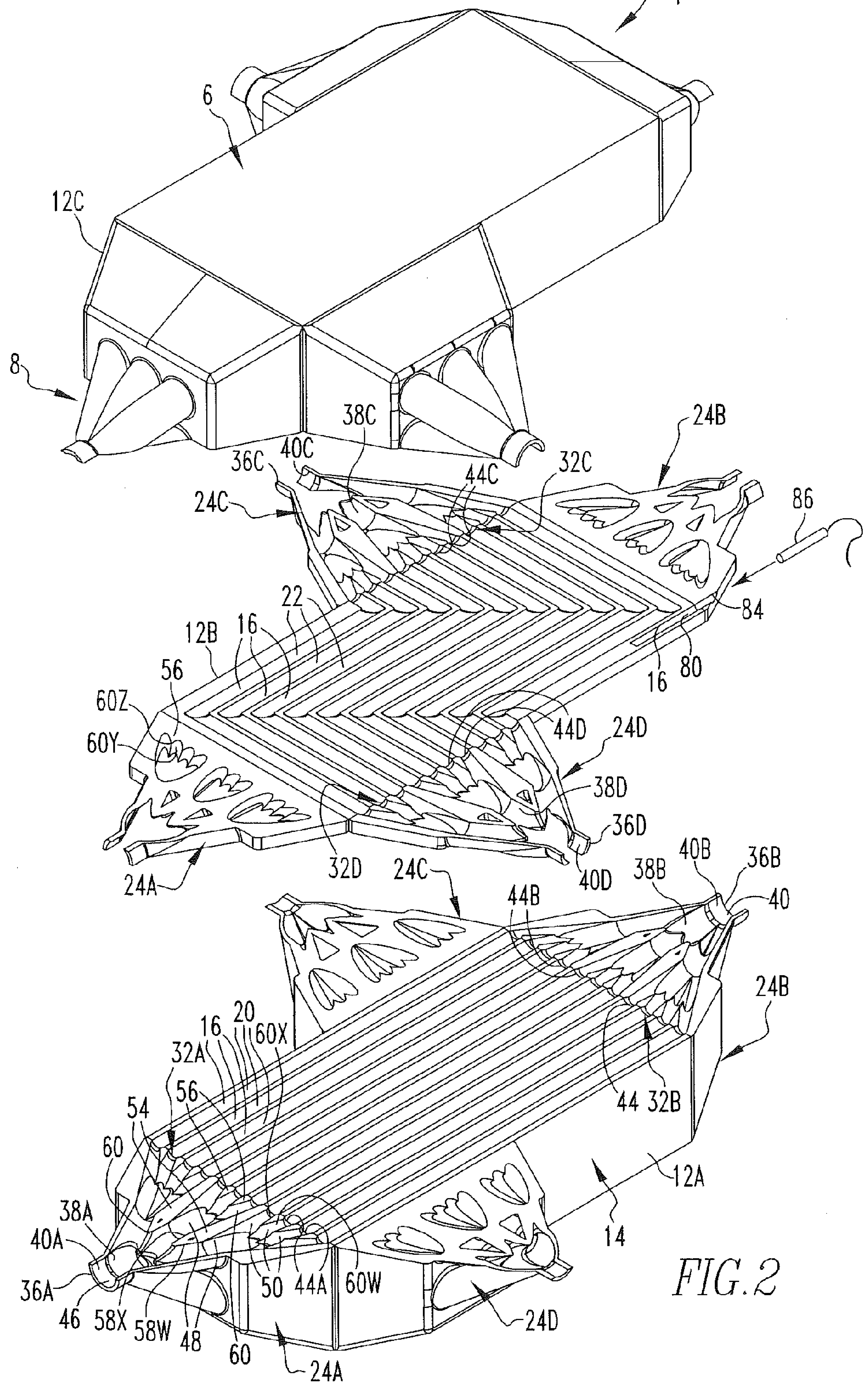

4
8
24C
24B
36C
36B
4
32B
40C
32C
40B
6
32
32D
32A
4
64
14
68
40D
40A
36A
36D
24A
24
24D

FIG. 1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6
12C
8
38C
24B
40C
36C
32C
44C
24C
86
84
22
12B
16
80
16
56
60Z
44D
24D
60Y
38D
36D
40D
32D
24C
24A
40B
36B
44B
38B
40
24B
16
20
32A
60X
56
44
32B
54
60
12A
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36A
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58X
58W
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44A
60W
24D
60
24A

FIG.2

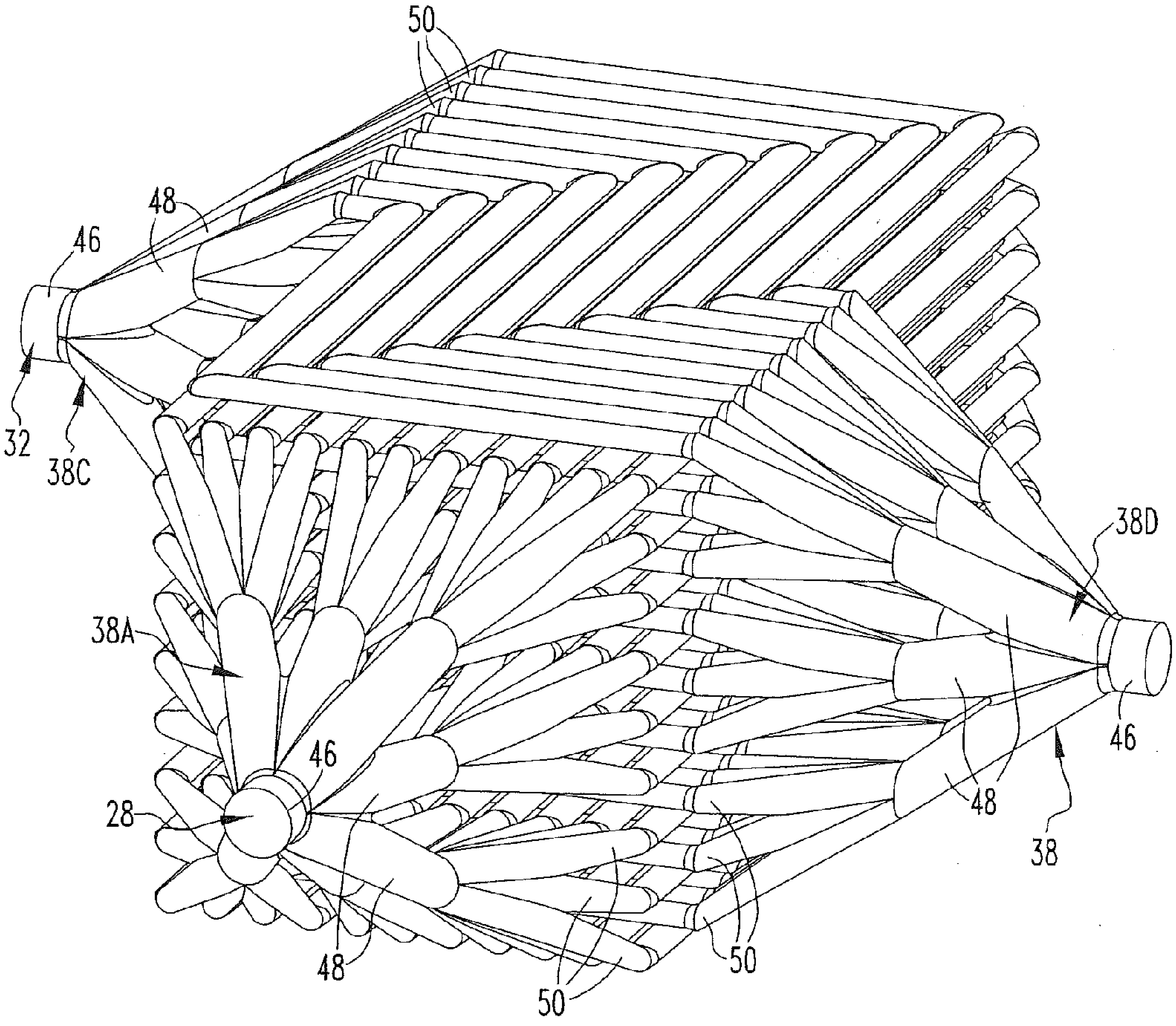
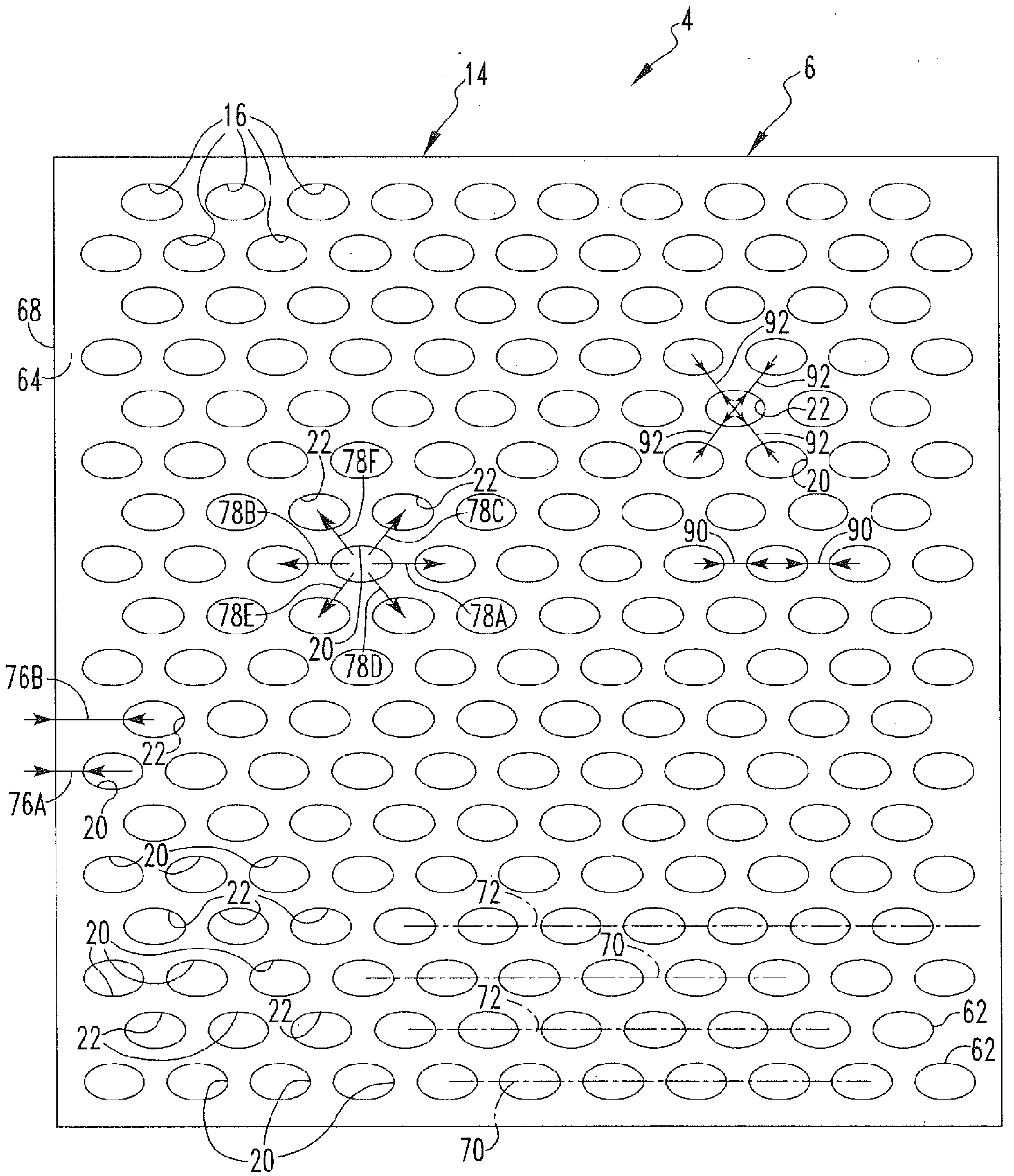


FIG. 3


4
14
6
16
68
64
92
92
22
92
92
20
22
78F
22
78B
78C
90
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78E
78A
20
78D
76B
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76A
20
20
22
72
20
70
72
22
22
62
62
20
70

FIG. 4

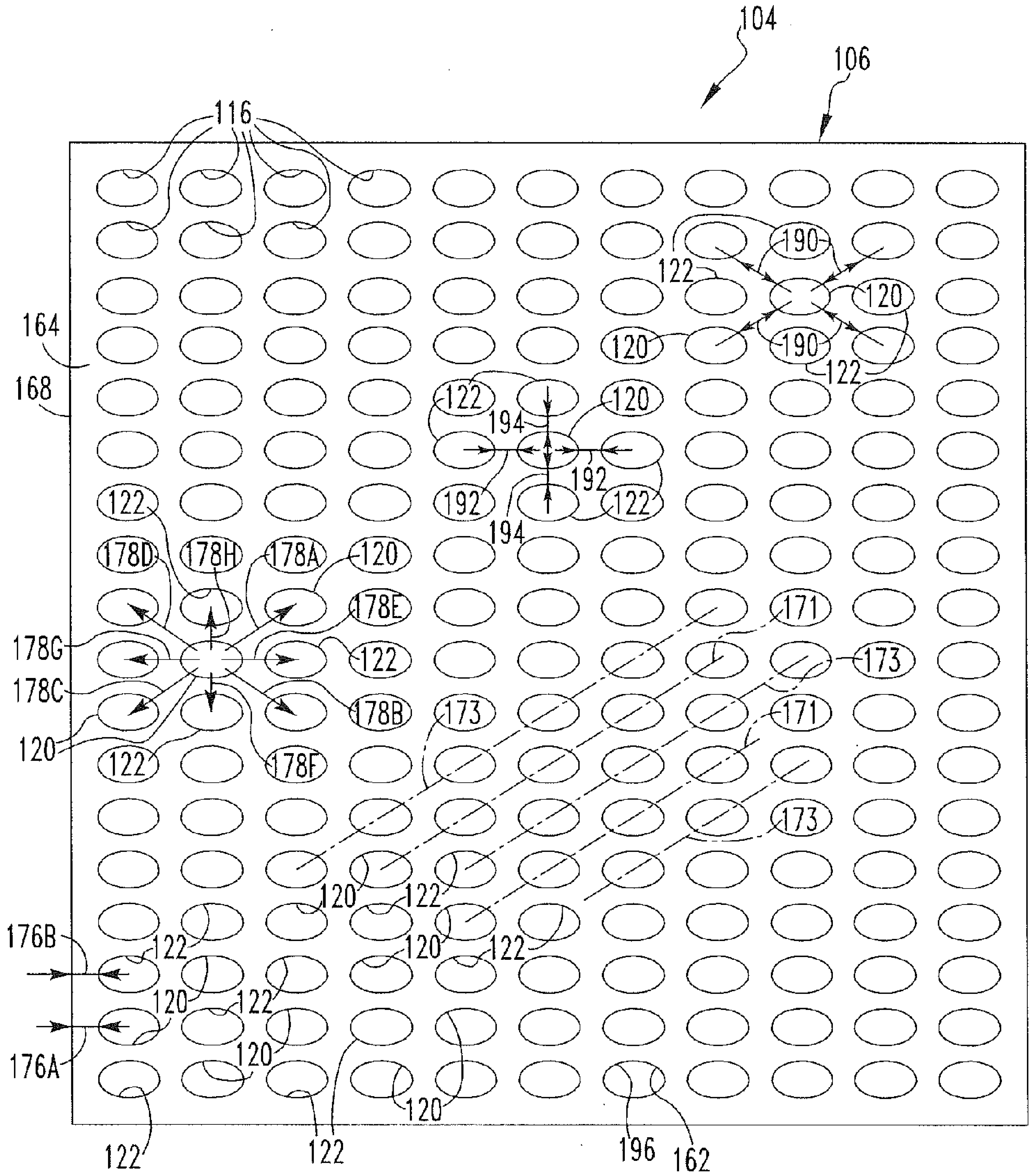

104
106
116
164
168
122
190
120
194
192
178D
178H
178A
178E
178G
178C
178B
178F
171
173
176B
176A
196
162

FIG. 5

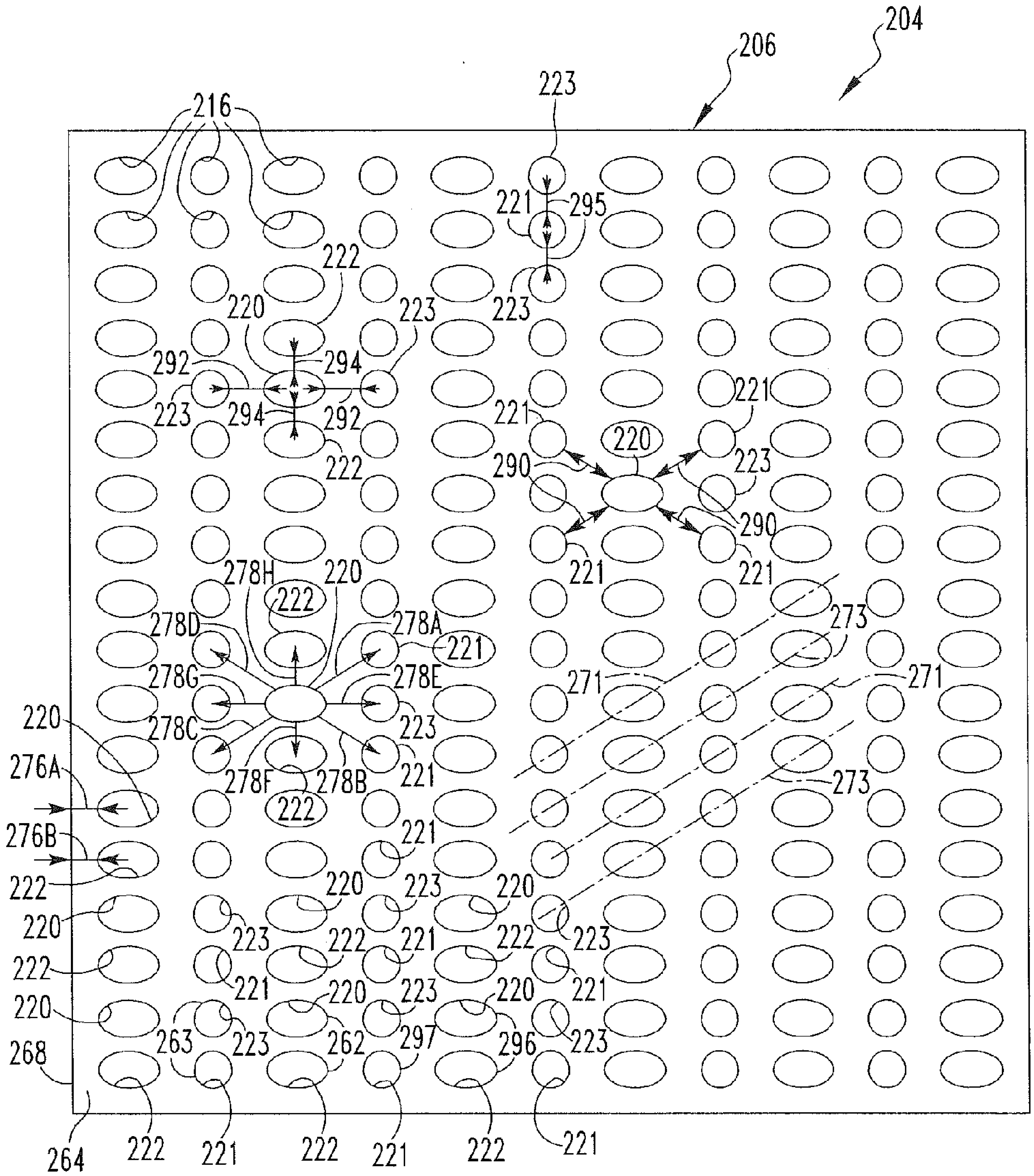
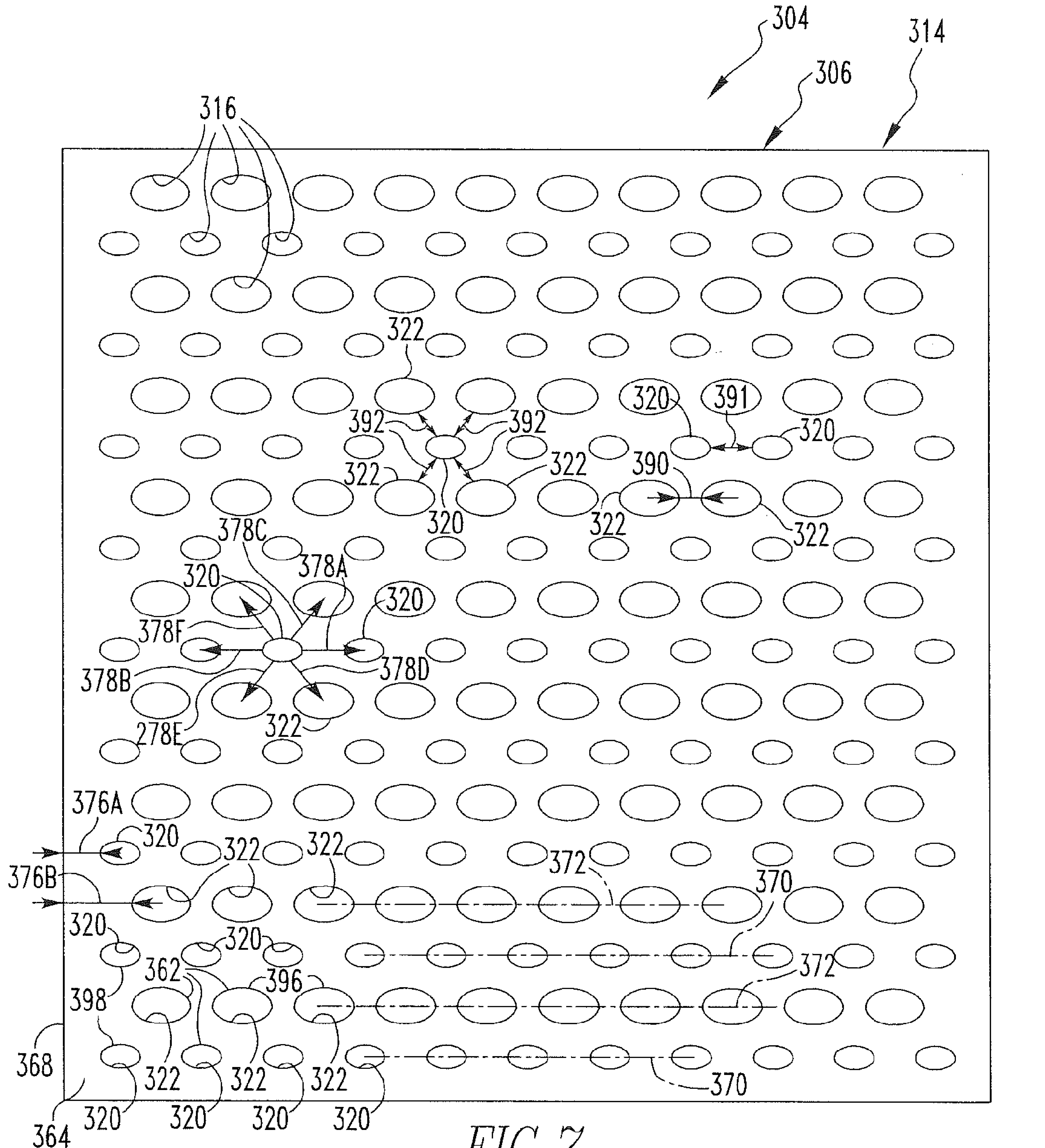

204
206
216
223
221
295
222
220
292
294
290
278H
278A
278D
278G
278E
278C
278F
278B
271
273
276A
276B
262
263
296
297
268
264

FIG. 6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306
314
316
322
320
391
392
392
322
322
390
320
322
322
378C
378A
320
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378F
378B
378D
278E
322
376A
320
322
322
372
376B
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362
396
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398
368
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364
320
320
320
320

FIG. 7

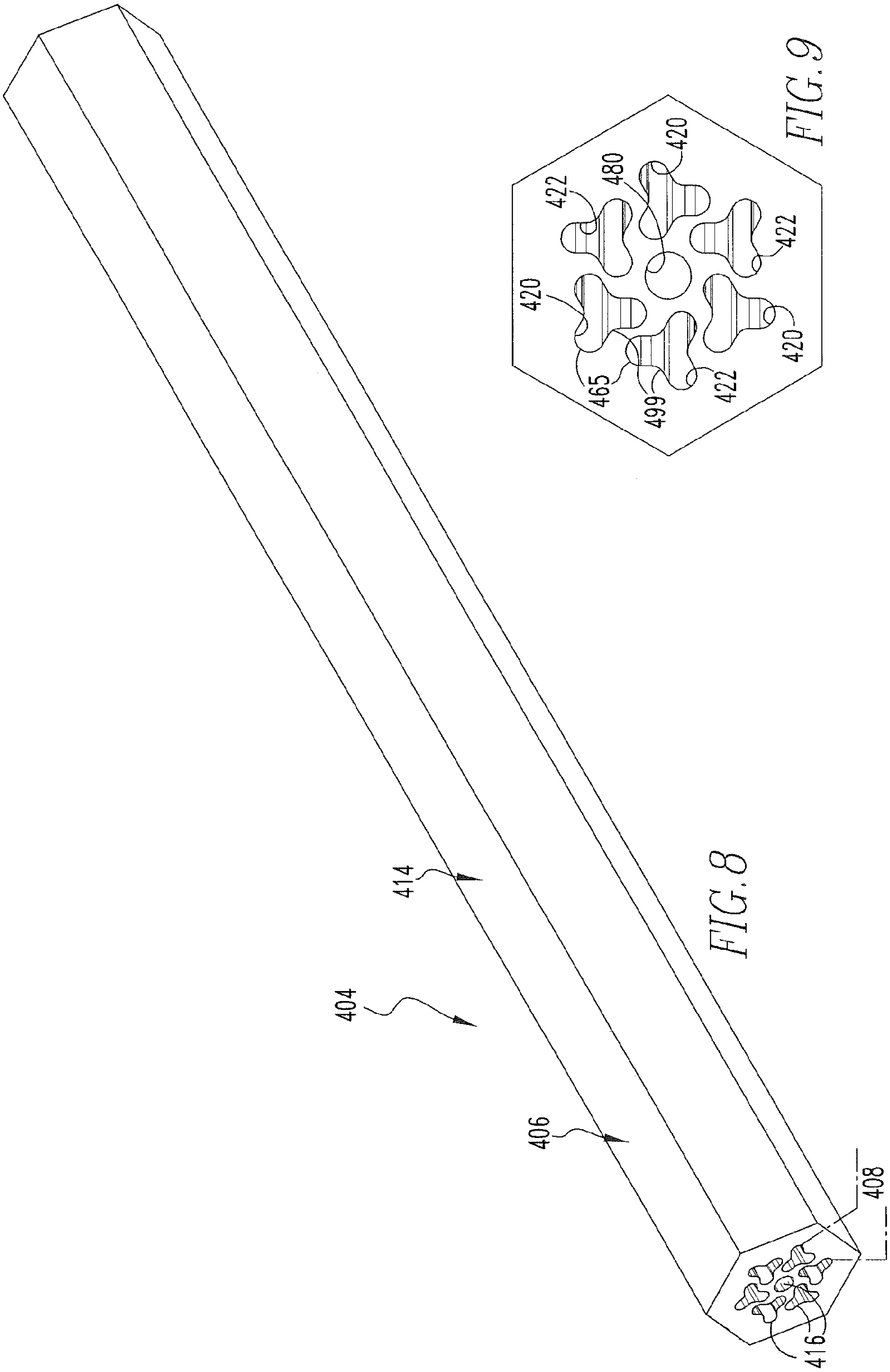

FIG. 9

FIG. 8

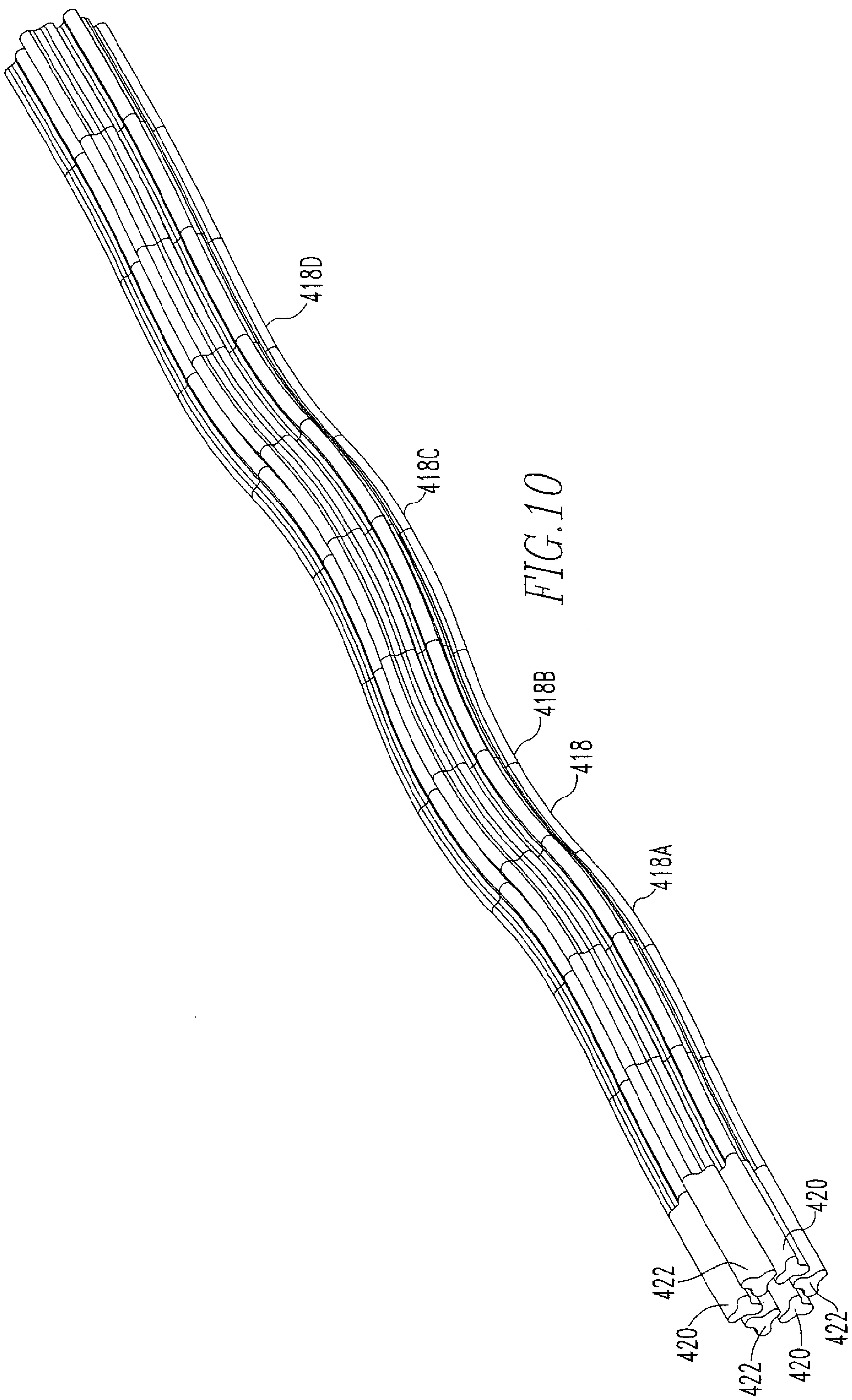

FIG.10

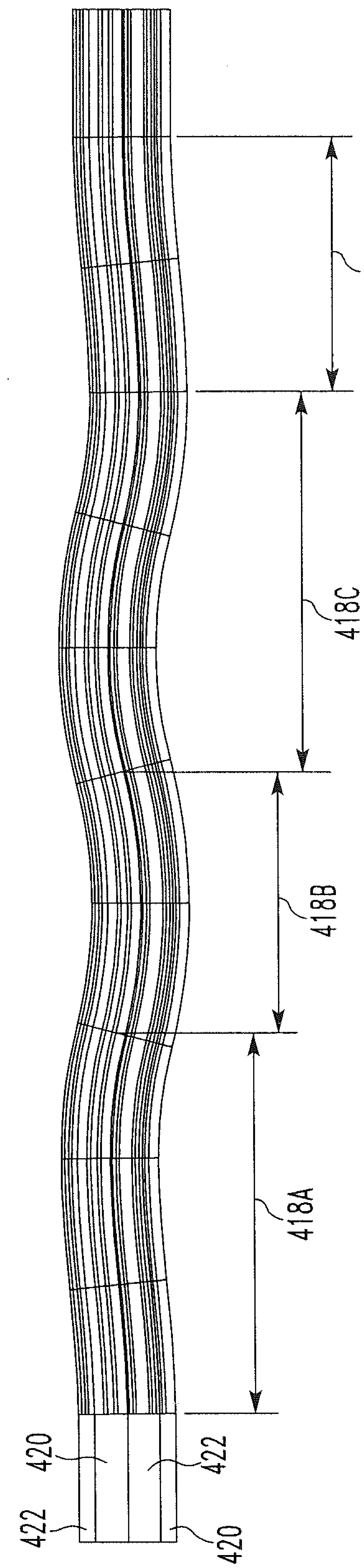

FIG.11

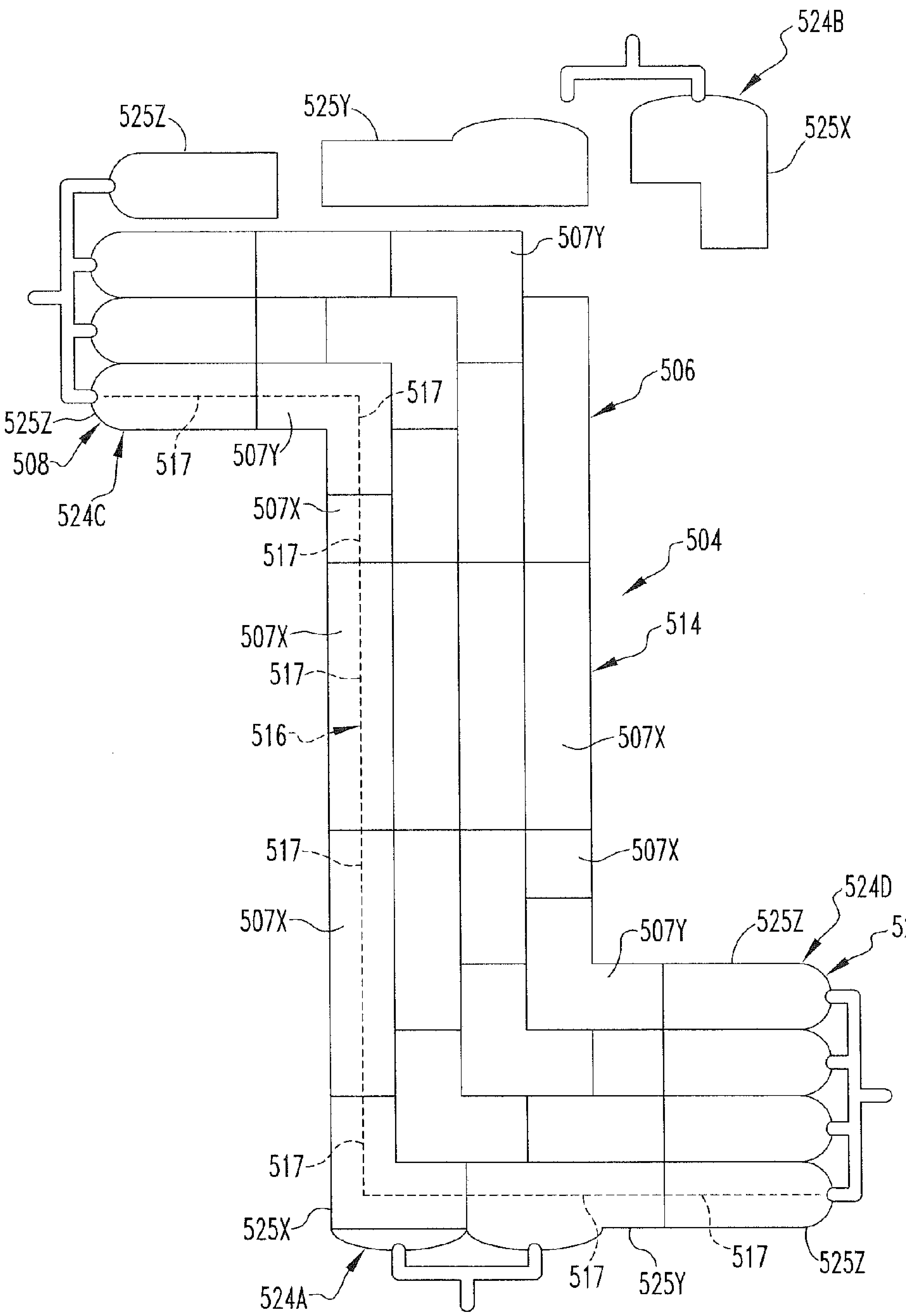
524B
525Z
525Y
525X
507Y
506
525Z
517
508
517
507Y
524C
507X
517
504
507X
517
514
516
507X
517
507X
507X
524D
525Z
524
507Y
517
525X
517
525Y
517
525Z
524A

FIG.12

HEAT EXCHANGER

BACKGROUND

[0001] 1. Field

[0002] The disclosed and claimed concept relates generally to compact heat exchangers and, more particularly, to a compact heat exchanger formed via additive manufacturing.

[0003] 2. Related Art

[0004] Heat exchangers typically each include a hot leg that receives a fluid at a first temperature and a cold leg that receives a separate fluid of a second, lower temperature, with the two legs being in heat transfer relation with one another to cause heat from the fluid in the hot leg to be transferred to the fluid in the cold leg. While heat exchangers have been generally effective for their intended purposes, they have not been without limitation.

[0005] Since a compact heat exchanger involves some type of an interface, such as one formed of metal or other heat conductive material, between the relatively hotter fluid and the relatively colder fluid, the interface itself experiences stresses, both from thermal differences and pressure differences between the two fluids and due to other factors. Such stresses can be harmful to the long term resilience of the compact heat exchanger. However, current manufacturing methodologies have met with limited success in cost-effectively protecting compact heat exchangers from warping and damage due to such stresses.

[0006] Additionally, the efficiency of any given compact heat exchanger is dependent upon, among other factors, the configurations of the flow channels in the hot leg and in the cold leg. Known manufacturing methodologies of compact heat exchangers have placed limits upon the ways in which the channels can be configured, with the result that compact heat exchangers have had limited performance Improvements thus would be desirable.

SUMMARY

[0007] An improved heat exchanger is formed from a plurality of very thin layers that are affixed to one another and that are Ruined via additive manufacturing. Such additive manufacturing enables the configurations of the heat exchanger's flow channels and the arrangements of such flow channels to be optimized for improved heat transfer performance, for improved resistance to thermal and mechanical stresses, and for optimization based upon other factors such as the environment in which the heat exchanger will be situated.

[0008] Accordingly, an aspect of the disclosed and claimed concept is to provide an improved heat exchanger formed from a plurality of layers that are affixed to one another via additive manufacturing.

[0009] Another aspect of the disclosed and claimed concept is to provide a heat exchanger having channels that are optimized for heat transfer.

[0010] Another aspect of the disclosed and claimed concept is to provide an improved heat exchanger having channels that are optimized to reduce thermal and mechanical stresses thereon.

[0011] Another aspect of the disclosed and claimed concept is to provide an improved heat exchanger that is formed from a plurality of layers affixed to one another wherein a layer includes one of: less than the entirety of a header of the heat exchanger, a portion of a core having at least a portion of a first channel and at least a portion of a second channel that are fluidly isolated from one another, or at least a portion of a channel and at least a portion of a header.

[0012] Accordingly, an aspect of the disclosed and claimed concept is to provide an improved compact heat exchanger that can be generally stated as including a plurality of layers affixed to one another and together forming a core and a header apparatus, the core having formed therein a plurality of channels, the plurality of channels comprising a number of first channels and a number of second channels, at least a portion of the number of first channels being position for being in heat transfer relation with at least a portion of the number of second channels, the header apparatus comprising at least a first header that is in fluid communication with at least some of the channels of the number of channels, the at least first header having a channel end and a connection end, the channel end being situated adjacent the core and including a number of flow connections that are in direct fluid communication with the at least some of the channels, the connection end having an opening that is structured to be connected in fluid communication with another flow structure, the at least one header comprising a flow passage that extends between the channel end and connection end and that enables fluid communication between the number of flow connections and the opening. At least one of the layers of the plurality of layers is at least one of: a layer that can be generally stated as including a portion of but less than the entirety of the at least first header and that has formed therein at least a portion of the flow passage, a layer that can be generally stated as including at least a portion of the core having formed therein at least a portion of a first channel and at least a portion of a second channel that are fluidly isolated from one another, and a layer that can be generally stated as including at least a portion of the core having formed therein at least a portion of a channel of the plurality of channels and that further comprises a portion of the at least first header and that has formed therein at least a portion of the flow passage.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] A further understanding of the disclosed and claimed concept can be gained from the following Description when read in conjunction with the accompanying drawings in which:

[0014] FIG. **1** is a perspective view of an improved compact heat exchanger in accordance with a first embodiment of the disclosed and claimed concept;

[0015] FIG. **2** is an exploded diagrammatic view of the heat exchanger of FIG. **1**;

[0016] FIG. **3** is a depiction of a fluid flow path of a first leg and a second leg of the heat exchanger of FIG. **1** situated in heat transfer relation;

[0017] FIG. **4** is a typical sectional view as taken along line **4-4** of FIG. **1**;

[0018] FIG. **5** is a view similar to FIG. **4**, except depicting a sectional view of an improved compact heat exchanger in accordance with a second embodiment of the disclosed and claimed concept;

[0019] FIG. **6** is a view similar to FIG. **5**, except depicting a sectional view of an improved heat exchanger in accordance with a third embodiment of the disclosed and claimed concept;

[0020] FIG. 7 is a view similar to FIG. 4, except depicting a sectional view of an improved heat exchanger in accordance with a fourth embodiment of the disclosed and claimed concept;

[0021] FIG. 8 is a schematic depiction of an improved compact heat exchanger in accordance with a fifth embodiment of the disclosed and claimed concept;

[0022] FIG. 9 is an end view of the heat exchanger of FIG. 8;

[0023] FIG. 10 is a depiction of the flow channels of the compact heat exchanger of FIG. 8;

[0024] FIG. 11 is another view of the flow channels that are depicted in FIG. 10; and

[0025] FIG. 12 is a schematic depiction of an improved compact heat exchanger in accordance with a sixth embodiment of the disclosed and claimed concept.

[0026] Similar numerals refer to similar parts throughout the specification.

DESCRIPTION

[0027] An improved compact heat exchanger 4 in accordance with a first embodiment of the disclosed and claimed concept is depicted in FIGS. 1 and 2. The compact heat exchanger 4 is formed via additive manufacturing. For instance, and without limitation, additive manufacturing can be performed by placing successive layers of powdered metal particles or other types of particles atop one another and selectively applying a laser, ion beam, or other form of concentrated energy to each layer of metal particles to fuse certain of the metal particles together and/or to another layer. When finished, the stack of layers of metal particles typically include some metal particles that have been fused together to form a resultant product and other metal particles that are unfused. The application of a blast of compressed air to the stack of layers of metal particles removes the unfused metal particles from the fused metal particles to result in a finished product. If desired, the finished product can undergo further processing via sintering or other processing to reduce the porosity that is inherent in additive manufacturing. Another type of additive manufacturing involves sticking the metal powders together using a polymorphic binder, followed by sintering to fuse the particles together. Other such technologies exist and are likewise usable in the instant application. As will be set forth in greater detail below, the novel and inventive use of additive manufacturing to form the heat exchanger 4 advantageously enables the heat exchanger 4 to be configured for optimized heat transfer and/or optimized resistance to thermal and mechanical stresses and/or other optimizations.

[0028] The improved heat exchanger 4 can be said to include a core 6 and a header apparatus 8 that are co-formed in situ as part of an additive manufacturing process. That is, the heat exchanger 4 comprises a plurality of layers, such as are indicated at the numerals 12A, 12B, and 12C in FIG. 2, that are affixed to one another and that are co-formed as a single piece unit. It is understood that FIG. 2 is intended to schematically represent that the heater exchanger 4 is formed from a plurality of layers, and that these plurality of layers are represented by the layers 12A, 12B, and 12C. It is further understood, however, that the use of additive manufacturing would more typically employ numerous layers far greater in quantity than the three layers that are expressly depicted individually in FIG. 2. That is, the layers 12A, 12B, and 12C would likely themselves each include a large number of separate layers that are individually fused to other layers using an additive manufacturing process, and the depiction of the layers 12A, 12B, and 12C in FIG. 2 is thus intended to be merely illustrative of an additive manufacturing process rather than expressly depicting the performance of such a process.

[0029] As can be understood from FIGS. 1 and 2, the core 6 can be said to include a core body 14 that is formed of the fused metallic material, and the core body 14 can be seen to include a plurality of channels 16 that are formed therein. The channels 16 are typically elongated, and some of the channels 16 may have more than one direction of elongation. The channels 16 include a plurality of first channels 20, such as are depicted in FIG. 2 as appearing on the layer 12A, and a plurality of second channels 22 that are depicted in FIG. 2 as appearing on the layer 12B. As will be set forth in greater detail below, the plurality of channels 16 can optionally include a number of other channels 16 that are provided for other purposes. As employed herein, the expression "a number of" and variations thereof shall refer broadly to any non-zero quantity, including a quantity of one.

[0030] The header apparatus 8 can be said to include a plurality of headers that are indicated, as in FIG. 1, at the numerals 24A, 24B, 24C, and 24D, it being noted that such headers may be referred to herein individually or collectively with the numeral 24. The heat exchanger 4 is, in the example presented herein, a counter current heat exchanger with cross flow in the regions near at least some of the headers 24. As such, among the exemplary headers 24, the header 24A is an exemplary first inlet header, and the header 24B is an exemplary second outlet header. The headers 24A and 24B are in fluid communication with the first channels 20 to form a first leg 28 that is show in FIG. 3 and which, in the depicted exemplary embodiment, is a cold leg. The header 24C is an exemplary second inlet header, and the header 24D is an exemplary second outlet header. The headers 24C and 24D are in fluid communication with the second channels 22 to form a second leg 30 that is likewise depicted in FIG. 3 and which, in the depicted exemplary embodiment, is a hot leg. The first and second legs 28 and 30, i.e., the exemplary cold and the exemplary hot leg, are situated in heat transfer relation with one another and are depicted in FIG. 3 in the absence of the core body 14. It is expressly noted that the use of the terms "cold" and "hot" and the like herein is intended to be merely exemplary in nature and is intended to be completely non-limiting.

[0031] As can further be understood from FIG. 2, the headers 24A, 24B, 24C, and 24D each include a channel end 32A, 32B, 32C, and 32D, respectively, that may be referred to herein individually or collectively with the numeral 32. Each channel end 32 is situated directly adjacent and in fluid communication with various of the channels 16. The headers 24A, 24B, 24C, and 24D each further include a connection end 36A, 36B, 36C, and 36D, respectively, that are each situated opposite the respective channel end 32 and that are structured to be connected in fluid communication with another flow structure such as a pipe or the like without limitation. The headers 24A, 24B, 24C, and 24D can each be said to have formed therein a flow passage 38A, 38B, 38C, and 38D, respectively, which may be referred to herein individually or collectively with the numeral 38. The flow passages 38 each extend between the respective channel end

32 and the respective connection end **36** and permit fluid communication between the headers **24** and the first and second channel **20** and **24**.

[0032] As can be best understood from the layers **12**A and **12**B in FIG. **2**, the headers **24**A, **24**B, **24**C, and **24**D each include an opening **40**A, **40**B, **40**C, and **40**D, respectively, which may be referred to herein individually or collectively with the numeral **40**. The openings **40** are situated at the respective connection end **36**. The headers **24**A, **24**B, **24**C, and **24**D each further include a plurality of flow connections **44**A, **44**B, **44**C, and **44**D, respectively, that may be referred to herein individually or collectively with the numeral **44**. The flow connections **44** are each in direct fluid communication either with one the first channels **20** or with one of the second channels **22**. The flow passages **38** extend between the openings **40** and the flow connections **44** and provide fluid communication therebetween and with the respective first and second channels **20** and **22**, as will be set forth in greater detail below. In this regard, it is reiterated that the headers **24**A and **24**B are in fluid communication with the first channels **20** to form the first leg **28**, and that the headers **24**C and **24**D are in fluid communication with the second channels **22** to form the second leg **30**, and it noted that the first leg **28** and the second leg **30** are fluidly isolated from one another and rather are situated in heat transfer relation with each other.

[0033] As can be understood from the layers **12**A and **12**B in FIG. **2**, each flow passage **38** includes a plurality of flow connections **44** that are in fluid communication with the corresponding opening **40** and, as mentioned above, are in direct fluid communication with the corresponding first channels **20** or second channels **22** that are in fluid communication therewith. The fluid flow through one of the openings **40** forms the comprehensive flow through the corresponding flow connections **44**, and vice versa.

[0034] The headers **24** are each configured to provide flow communication between the opening **40** and the plurality of corresponding flow connections **44** to provide direct fluid communication between the flow connections **44** and the corresponding first channels **20** or second channels **22**, much in the fashion in which blood vessels of a living creature include main flow channels and successively smaller secondary channels and tertiary channels, for example, in fluid communication therewith that directly feed whatever is in need of the provided fluid flow. This is in advantageous contrast to a conventional manifold of a flow system wherein a relatively large passage and a plurality of smaller passages are all in fluid communication with a common plenum that does not necessarily direct the fluid flow into or from the relatively smaller channels. In an example wherein fluid flows from a relatively large channel into a plenum and then into relatively smaller channels, the fluid flow impinges on the regions of the plenum that are situated adjacent its connections with the smaller channels. Such impingement results in stagnation of flow at such locations and consequent pressure drop and turbulence.

[0035] Likewise, in an example where fluid flows out of the relatively smaller channels and into the plenum and thereafter out of the relatively larger channel, the flow of fluid into the plenum is in the form of a free jet that experiences a pressure drop as the free jet mixes with the fluid within the plenum. Is such a situation, the regions of the plenum that do not aligned to receive fluid flow that is directed from the relatively smaller channels experiences areas of fluid stagnation and thus eddy currents and resultant turbulence. Such fluid flow in a plenum-type flow system is less than optimum due to the pressure drops and other flow limitations that necessarily occur with the exemplary plenum-based geometry and also due to the vibrations and mechanical stresses that are placed on such a flow system.

[0036] Advantageously, however, the headers **24** of the improved heat exchanger **4** are configured to provide improved fluid communication between the opening **40** and the corresponding flow passages **44**. As can further be seen in FIG. **2**, the exemplary flow connections **44** each include a first flow passage portion **46**, which is a portion of the fluid flow as it is flowing through the opening **40**. The exemplary flow connections **44** each further include a second flow passage portion **48** and a third flow passage portion **50**. The third flow passage portions **50** are situated at the channel end **32** and are what provide direct fluid communication to the connected first channels **20** or to the second channels **22**. The second flow passage portions **48** are each interposed between a corresponding first flow passage portion **46** and a corresponding third flow passage portion **50**. That is, the first, second, and third flow passages **46**, **48**, and **50** of any given flow connection **44** are sequentially connected together in fluid communication such that the fluid flow that occurs through the third flow passage portion **50** is a part of the comprehensive fluid flow through the corresponding first flow passage portion **46**, and vice versa.

[0037] In this regard, it can be seen that the headers **24** each include a number of primary flow directors **54** and a number of secondary flow directors **56** that provide flow direction between the openings **40** and the corresponding flow connections **44**. The exemplary secondary flow directors **56** are generally each situated adjacent the core **6** and between either a pair of first channels **20** or a pair of second channels **22**.

[0038] The following example relates to the header **24**A wherein fluid enters the opening **40**A and flows through the flow passage **38**A and out of the flow connections **44**A into the first channels **20** that in direct fluid communication therewith. In the header **24**A, the fluid initially flows through the opening **40**A and into the first flow passage portion **46** wherein it encounters a pair of external surface portions **58**W and **58**X of the primary flow directors **54** which direct the fluid to flow into the relatively smaller but more plentiful second flow passage portions **48**. The fluid flow in each second flow passage portion **48** thereafter encounters a pair of external surface portions **60**W and **60**X on each of the secondary flow directors **56** that divide the fluid flow from the second flow passage portion **48** into the relatively smaller but more plentiful third flow passage portions **50**. Another set of external surface portions **60**Y and **60**Z are shown in FIG. **2** on the layer **12**B as further dividing the fluid flow from the second flow passage portions **48**A that are depicted as being formed at least in part on the layer **12**A and which direct the fluid flow from such second flow passage portions **48**A into another set of first channels **20** that are situated at the underside of the layer **12**C and that are thus not expressly depicted in FIG. **2**.

[0039] The external surface portions **60**W, **60**X, **60**Y, and **60**Z, which may be referred to collectively or individually herein with the numeral **60**, thus form some of the third flow passage portions **50** by, in the example of the header **24**A, dividing and directing the flow of fluid from one of the second flow passage portions **48** into a plurality of relatively smaller third flow passage portions **50** and then directly into the first passages **20** that are in fluid communication therewith. The external surface portions **60** thus advantageously avoid at least some of the stagnation and pressure drop that would exist in the absence of the secondary flow directors **56**. Likewise, the external surface portions **58**W and **58**X divide and direct the flow from the first flow passage portion **46** into a larger number of relatively smaller second flow passage portions **48**. This reduces pressure drop and turbulence in flowing from the opening **40**A to the flow connections **44**A compared with a conventional manifold.

[0040] When fluid is flowing in the reverse direction through one of the headers **24**, such as with the outlet header **24**B, the primary flow directors **54** are in direct fluid communication with the corresponding first channels **20** and direct the flow from the third flow passage portions **50** into a relatively larger second flow passage portion **48**. Likewise, the primary flow directors **54** direct with minimal pressure drop the fluid flow from the second flow passage portions **48** into the first flow passage portion **46** of the header **24**B to permit the fluid to flow out of the opening **40**B and into another flow structure such as a connected pipe or the like.

[0041] It thus can be seen that by configuring the flow passages **38** to provide smooth fluid communication between one of the openings **40** and the corresponding flow connections **44**, reduced pressure drop is enabled, as is improved fluid flow having less turbulence and stagnation, all of which are desirable in a fluid flow environment. The aforementioned additive manufacturing process enables the improved heat exchanger **4** to be configured with its headers **24** designed in such a fashion, and this can be done in a relatively inexpensive fashion. The improved headers **24** of the improved heat exchanger **4** thus enable the heat exchanger **4** to have improved fluid flow performance in a cost-effective and mechanically reliable fashion, which is highly desirable and advantageous. Furthermore, the versatility and variability of the additive manufacturing process enables the design of the headers **24** to be optimized for fluid flow, i.e., designed with a computer system employing fluid system design software, and the completed design can be downloaded to an additive manufacturing machine that will simply manufacture the heat exchanger whose design was provided to it. Such optimization can be altered depending upon various needs of any given application to provide appropriate optimization, and such efficiency of modification is highly advantageous and desirable.

[0042] As can be seen in FIG. **4**, the first and second channels **20** and **22** are of a cross-sectional shape that is oriented transverse to the direction of flow therethrough and that has a perimeter **62** which, in the depicted exemplary embodiment, is arcuate, non-circular, and is of an approximately oval or elliptical or semi-elliptical shape. The shape of the perimeter **62** is an example of a cross-sectional shape of a flow channel that is optimized to provide low pressure drop while providing elevated rates of heat transfer. As will be explained in greater elsewhere herein, the shape of any given channel can be tailored to provide optimization for any of a wide variety of considerations such as thermal and mechanical stresses and to provide optimization based upon other considerations. The depicted exemplary first channels **20** and the depicted exemplary second channels **22** in FIG. **4** are depicted as being of the same shape and thus the same perimeter **62** or form factor and also being of the same size. Further in an exemplary fashion, the first channels **20** are arranged in FIG. **4** in a plurality of first rows **70**, and the second channels **22** are depicted in FIG. **4** as being likewise arranged in a plurality of second rows **72**, with the first rows **70** alternating with the second rows **72**. The perimeter **62** of the first and second channels **20** and **22** can be said to have a major axis that is longer than a minor axis thereof, and the major axes of the first channels **20** are aligned with one another along the various first rows **70**. The same can be said of the second channels **22** having their major axes aligned along the second rows **72**. The first and second rows **70** and **72** are oriented in the horizontal direction from the perspective of FIG. **4**. In the exemplary arrangement of the first and second channels **20** and **22** in FIG. **4**, a first row **70** of the first channels **20** is situated adjacent a second row **72** of second channels **22** which is, in turn, situated adjacent another first row **70** of the first channels **20**, etc.

[0043] As can further be seen in FIG. **4**, the core body **14** includes a wall **64** having a wall surface **68** that faces toward the exterior of the heat exchanger **4** and that faces generally away from the first and second channels **20** and **22**. The wall **64** could be said to be of a wall thickness **76**A between one of the first channels **20** and the wall surface **68** and to be of another wall thickness **76**B between one of the second channels **22** and the wall surface **68**. In this regard, the wall thickness **76**A would refer to the minimum thickness between the wall surface **68** and the perimeter **62** of the first channel **20** closest thereto. The wall thickness **76**B would likewise be defined as being the minimum distance between the wall surface **68** and the perimeter **62** of the second channel **22** that is closest thereto. In the exemplary embodiment depicted herein, it can be seen that the wall thickness **76**A is less than the wall thickness **76**B. The relatively greater wall thickness **76**B has advantageously been optimized, for instance, to provide greater stiffening of the core body **14** when, for example, the second channels **22** carry fluid that is of a relatively greater pressure, i.e., static pressure, than that carried by the first channels **20**. Such optimization can be based upon differences in static pressure, dynamic pressure, etc., and the various relationships between the wall thicknesses **76**A and **76**B that are presented herein are intended merely as examples of what such optimization might provide for use in a given exemplary environment.

[0044] It should be understood that other types of optimizations of the relationships among the first and second channels **20** and **22**, including their arrangement and the thicknesses of the wall **64** therebetween, etc., can be provided as needed. For instance, the first and second channels **20** and **22** are depicted in FIG. **4** as having various adjacent relationships with one another. Any given first or second channel **20** or **22** (a first channel **20** in the example presented in FIG. **4**) is situated adjacent another channel **16** with which it is in fluid communication, as is indicated at the numeral **78**A, and is further situated adjacent another such channel **16** with which it is likewise in fluid communication, as is indicated at the numeral **78**B. That is, in the depicted exemplary embodiment, at least some of the first channels **20** are each situated between a pair of other first channels **20** as indicated at the numerals **78**A and **78**B in the depicted exemplary embodiment. It is noted that some of the channels **16**, such as those at the periphery of the core **6**, may not necessarily possess all of the relationships indicated herein, although many of the other channels **16** do. The relationships **78**A and **78**B are oriented in the horizontal direction from the perspective of FIG. **4**, and the three identified first channels **20** are in the same first row **70**.

[0045] The aforementioned first channel **20** that is situated between the two adjacent first channel **20**, as is indicated at the numerals **78**A and **78**B, is further adjacent four other channels **16** with which it is fluidly isolated, i.e., four adjacent second channels **22**, as is indicated with the numerals **78**C, **78**D, **78**E, and **78**F. The indicated relationships **78**C, **78**D, **78**E, and **78**F are oriented in directions that are neither vertical nor horizontal from the perspective of FIG. **4** and rather are each of an oblique or diagonal orientation in FIG. **4**.

[0046] As is indicated by the adjacent relationships **78**A and **78**B, it can be seen that the indicated adjacent first channels **20** are separated from one another by a first distance **90**, meaning that the core body **14** is of a minimum thickness between the adjacent pairs of first channels **20** that is equal to the first distance **90**. The exemplary first distance **90** is equal between both adjacent pairs of the first channels **20** in the depicted exemplary embodiment. It is reiterated that this first distance **90** is the distance between adjacent channels **16** that are in fluid communication with one another in the example of FIG. **4**.

[0047] Such a first channel **20** can further be said to be of a second distance **92** from the four other channels **16** that are adjacent thereto and that are fluidly isolated from the first channel **20**, i.e., the four second channels **22** that are indicted with the adjacent relationships **78**C, **78**D, **78**E, and **78**F, and the distance is equal to a second distance **92**. The second distance **92** represents the minimum thickness of the core body **14** between one of the first channels **22** and each of the adjacent second channels **22** that are fluidly isolated from the first channel **20**. In the depicted exemplary embodiment, the second distances **92** are depicted, for instance, as being equal to one another.

[0048] In this regard, it can be understood that the first distances **90** and the second distances **92** can be adjusted as needed to provide optimization between the various considerations of heat transfer rate, thermal and mechanical stresses, flow rates and pressures, and other considerations that may exist in creating the design of the heat exchanger **4**.

[0049] It is also noted that each of the first and second channels **20** and **22** in FIG. **4** is depicted as having a cross-sectional area **96** that is equal to one another. Again, the cross-sectional areas **96** can be adjusted as needed in conjunction with any of the other optimizations that may be needed or provided in order to optimize the various performance factors mentioned herein and/or other factors.

[0050] As can be further seen in FIG. **2** and in particular on the layer **12**B, the plurality of channels **16** further include an additional channel **80** that is formed in the wall **64** between one of the first channels **20** and the wall surface **68** adjacent thereto. The additional channel **80** is elongated and includes an opening **84** to the exterior of the heat exchanger **4** and is configured to receive therein an instrument **86** of one kind or another. For instance the instrument **86** could be a device such as a temperature sensor or the like, in which case the additional channel **80** would be an instrumentation channel. Similarly, the instrument **86** could instead be a number of heaters that are configured to preheat the heat exchanger **4** to reduce thermal shock when cold and hot fluids are first introduced into the channels **16**. Such heating would be particularly advantageous during thermal cycling to reduce the possible deleterious effects of a sudden onset of thermal stress on the core **6**. In the case of the instrument **86** being a number of heaters, the additional channel **80** might be one or more such additional channels **80** that may be positioned elsewhere on the core **6** than is expressly depicted in FIG. **2** and would receive the number of heaters therein.

[0051] It is noted that the additional channel **80** is a part of the overall design of the heat exchanger **4**, and the wall **64** thus can be optimized to resist the concentration of thermal and mechanical stresses and other stresses that may otherwise result from the additional channel **80** being formed at a discrete location on the heat exchanger **4**. In this regard, the dimensions of the core body **14** in the vicinity of the additional channel **80** can be configured to be heavier, as needed, or the additional channel **80** could alternatively be positioned in a different location on the core body **14** with relatively minimal and/or mechanical stresses and/or based upon other considerations.

[0052] The additional channel **80** is formed in the heat exchanger **4** during initial manufacture thereof during the additive manufacturing process, with the result that the additional channel **80** would be free work hardening or other residual stresses that might result from forming the additional channel **80** with, for example, a drill bit applied to the wall **64**. It is also noted that the opening **84** is situated on a surface of the header **24**B that is oblique to the longitudinal extent of the additional channel **80**, which would typically be very difficult to drill from such an angle if a conventional drill bit would be used. While other processes such as lasers and the like can be employed in such a scenario to enable the drilling of such an additional channel or a pilot hole therefor in such an opening relationship to an exterior surface. It is noted, however, that the use of such lasers or other methodologies is costly compared with the advantageously minimal cost to form the additional channel **80** when using the additive manufacturing process mentioned herein.

[0053] It thus can be understood that the heat exchanger **4** is designed in such a fashion that its various structures and the first and second legs **28** and **30** are together optimized to provide an overall design that provides desirable, i.e., optimized, characteristics for pressure drop, thermal and mechanical stresses, heat transfer efficiency, and based upon other considerations. Depending upon the needs of the particular application, the various interrelationships among the parts of the heat exchanger **4** and the parts of the first and second legs **28** and **30** can be adjusted depending upon the needs of the particular application to advantageously provide other optimization that is optimized to meet other needs of other applications such as varying pressures and temperatures, and other such considerations, at minimal cost.

[0054] An improved heat exchanger **104** similar to the heat exchanger **4** is schematically depicted in FIG. **5** and is represented by the sectional view that is similar to the sectional in FIG. **4** of the heat exchanger **4**. The heat exchanger **104** may be configured to look identical to the heat exchanger **4** from the exterior, although this need not necessarily be the case.

[0055] The heat exchanger **104** includes a core **106** having formed therein a plurality of channels **116** that are elongated and that include a plurality of first channels **120** and a plurality of second channels **122**. The first channels **120** are in fluid communication with one another, and the second channels **122** are likewise in fluid communication with one another, with the first channels **120** being fluidly isolated from the second channels **122**.

[0056] In the exemplary embodiment configured in FIG. **5**, the first and second channels **120** and **122** are of a shape having an arcuate and non-circular perimeter **162**, all of which are of the same size and shape as one another. For the sake of completeness, it is reiterated that the sizes and/or shapes could be varied as needed depending upon the needed optimization of the heat exchanger **104** in the particular environment in which it is intended to be used. The core **106** has a wall **164** having a wall surface **168**, and the first and second channels **120** and **122** are of equal distances from the wall surface **168**. That is, the wall **164** is of a minimum wall thickness **176**A between the wall surface **168** and a first channel **120** adjacent thereto, and the wall thickness **176**A is equal to another minimum wall thickness **176**B between the wall surface **168** and a second channel **122** adjacent thereto. Again, such wall thicknesses can be optimized depending upon the needs of the particular application.

[0057] As can further be understood from FIG. **5**, the first and second channels **120** and **122** are of a different arrangement than the first and second channels **20** and **22** in the heat exchanger **4** as depicted in FIG. **4** inasmuch as the first channels **120** and the second channels **122** are not arranged in horizontal rows of channels that are in fluid communication with one another. It is reiterated that the rows in FIG. **4** are aligned with the major axes of the first and second channels **20** and **22**, which is not the case with the first and second channels **120** and **122** in FIG. **5**. Rather, each first channel **20** is adjacent four channels **116** with which it is fluidly isolated, i.e., four of the second channels **122**, and is further adjacent another four other channels **116** with which it is in fluid communication, i.e., four other first channels **120**. For example, FIG. **5** depicts one of the first channels **120** as having four adjacent relationships **178**A, **178**B, **178**C, and **178**D with four other adjacent first channels **120** with which it is in fluid communication. The adjacent relationships **178**A, **178**B, **178**C, and **178**D are oriented neither in the horizontal direction nor in the vertical direction with respect to FIG. **5** and rather are in an oblique direction or in a diagonal orientation. This same first channel **120** and other such first channels **120** are each further adjacent four other channels **116** with which it is fluidly isolated and is situated in heat transfer relation, i.e., four of the second channels **122**, as is indicated at the adjacent relationships **178**E, **178**F, **178**G, and **178**H. The exemplary adjacent relationships **178**E, **178**F, **178**G, and **178**H are oriented in the horizontal and vertical directions from the perspective of FIG. **5**, by way of example. It can be seen that the channels **116** adjacent the wall surface **168** are not each necessarily adjacent four other channels **116** with which it is in fluid communication and another four channels **116** from which it is fluidly isolated, but it is understood that other channels **116** of the exemplary heat exchanger **104** do share such a relationship. Such an interrelationship between the first channels **120** and the second channels **122** would, as a general matter, typically be capable of providing a greater rate of heat transfer between the first channels **120** and the second channels **122** compared with, for instance, the heat exchanger **4**. Such an arrangement of first and second channels **120** and **122** as in FIG. **5** might be the result of optimization for a certain purpose such as optimized heat transfer in the set of circumstances for which the heat exchanger **104** was intended to be used.

[0058] It can further be seen that the adjacent relationships **178**A, **178**B, **178**C, and **178**D are each of an equal first distance **190**. The adjacent relationships **178**E and **178**G are in the horizontal direction from the perspective of FIG. **5** and indicate that a second distance **192** separates the first channel **120** from two of the adjacent second channels **122**, the two second distances **192** being equal to one another. The first channel **120** is further spaced a third distance **194** in the vertical direction from the perspective of FIG. **5** between the other two adjacent second channels **122** that are indicated with the relationships **178**F and **178**H, the third distances **194** being equal to one another. It can be seen that the first distances **190**, i.e., the distances between the first channels **120** that are in fluid communication with one another and are thus potentially of the same or similar temperature, is greater than either of the second distances **192** and the third distances **194**. The second and third distances **192** and **194** are distances between the first channel **120** and the second channels **122** with which the first channel **120** is fluidly isolated and which likely would be of another temperature and in a heat transfer relationship with the first channel **120**. Such relative positioning, as is indicated by the first, second, and third distances **190**, **192**, and **194**, i.e., thicknesses of the wall **164**, provide a further example of how heat transfer rates and efficiency can be optimized or adjusted depending upon needs of any particular application.

[0059] It is further noted that the first and second channels **120** and **122** are of the same cross-sectional area **196** in a direction that is transverse to the direction of flow therein. It is reiterated that this similarity of cross-sectional areas **196** is one of a plurality of relationships that can be adjusted to provide performance that meets any of a variety of criteria for suitability in a given application.

[0060] An improved heat exchanger **204** in accordance with a third embodiment of the disclosed and claimed concept is depicted schematically by the cross-sectional view of its core **206** in FIG. **6**. The core **206** has a plurality of elongated channels **216** formed therein that include a plurality of first channels **220** and **221** in fluid communication with one another and a plurality of second channels **222** and **223** that are in fluid communication with one another. The exemplary first channels **220** and the exemplary second channels **222** are each of a cross-sectional shape having a perimeter **262** that is of the same size and shape as the exemplary perimeter **162** of the first and second channels **120** and **122** in FIG. **5**, i.e., oval or elliptical or semi-elliptical. It is noted, however, that the first channels **221** and the second channels **223** are of an arcuate shape that is of a circular perimeter **263**. The first and second channels **220** and **222** are of one cross-sectional area **296**, and the first channels **221** and the second channels **223** are of another cross-sectional area **297** which, in the depicted exemplary embodiment, is smaller than the cross-sectional area **296**.

[0061] The first channels **220** and **221** generally each share the same type of interrelationship (except perhaps at the periphery of the core **206**) with the second channels **222** and **223** as evidenced by the adjacent relationships **278**A, **278**B, **278**C, **278**D, **278**E, **278**F, **278**G, and **278**H that are positionally similar to the adjacent relationships **178**A, **178**B, **178**C, **178**D, **178**E, **178**F, **178**G, and **178**H. It is noted, however, that by providing the first and second channels **221** and **223** to have the relatively smaller cross-sectional area

297, the first distances 290 between any of the first channels 220 or 221 and the four other first channels 220 or 221 that are diagonally adjacent (according with the adjacent relationships 278A, 278B, 278C, and 278D) are greater than the first distances 190 in FIG. 5. Likewise, the first distances 290 are greater than the second distances 292 indicated by the adjacent relationships 278E and 278G between a channels 216 and a pair of horizontally adjacent other channels 216 that are not in fluid communication therewith and rather are fluidly isolated therefrom. Such second distances 292 are likewise greater than the third distances 294 and the fourth distances 295 that are represented in the vertical direction from the perspective of FIG. 6 between vertically adjacent pairs of first and second channels 220 and 222 and between vertically adjacent first and second channels 221 and 223, respectively. Again, such spacings and interrelationships provide relative proximity or relative distance between adjacent channels 216 in a fashion that can optimize heat transfer and/or can optimize the structural material of the core 206 that is situated between channels 216 that are fluidly isolated from one another and between which thermal and mechanical stresses would exist.

[0062] It can further be seen from FIG. 6 that the first channels 220 are of one distance as at 276A from the wall surface 268 of the wall 264 and that the second channels 222 are of a second such distance 276B from the wall surface 268 that is equal to the distance 276A. Other relative, equal, and/or unequal wall thicknesses can be provided depending upon the needs of the particular application and the needed performance of the heat exchanger 204.

[0063] It thus can be understood that the positions among the various channels 216 and the various shapes and sizes of the various channels 216 can be selected based upon various optimization factors that relate to concerns regarding heat transfer capabilities, thermal and mechanical stresses, and other such factors. Other variations will be apparent.

[0064] While FIG. 6 is depicted herein as being an cross-sectional view that is taken of another heat exchanger 204 that is different than the heat exchanger 104 that is depicted in FIG. 5, it is understood that FIG. 6 could be used to alternatively depict the way in which the various channel 116 of FIG. 5 can change in size and shape from one longitudinal position along the channels 116 to another longitudinal position along the same channels. For example, FIG. 6 could alternatively depict that certain of the first channels 120 could transition from one location in a heat exchanger, represented by FIG. 5, to another location, represented by FIG. 6, in the same heat exchanger. For instance, certain of the first channels 120 in FIG. 5 could change their shape and cross-sectional area from being arcuate round at one position along their longitudinal extent, as is indicated at FIG. 5, to be of a difference arcuate shape and cross-sectional area at another position along their longitudinal extent, as is indicated in FIG. 6. The same thing could be said of certain second channels 122 that transition into relatively smaller circular second channels 223 between FIG. 5 and FIG. 6. Such changes in the sizes and shapes, for instance, of the various channels would correspondingly alter the dimensions of the walls of the core therebetween and also alter the flow characteristics of such channels. Such a design could result for the performance needs of the particular heat exchanger for the intended application. It thus is understood that any given channels in a heat exchanger need not be of a fixed cross-sectional shape or a fixed cross-sectional perimeter or cross-sectional area along the entirety of its longitudinal extent, and rather such dimensions and the corresponding wall dimensions can vary depending on particular needs of given applications. Likewise, the varying wall dimensions could be what are being optimized based upon the needed resistance to thermal and mechanical stresses in a given application, with the channel shapes and sizes being what results from such an optimization of the walls of the core.

[0065] Another example of such optimization is depicted in FIG. 7, which depicts another heat exchanger 304 in accordance with a fourth embodiment of the disclosed and claimed concept. The heat exchanger 304 has a core 306 with a core body 314 wherein its channels 316 transition from what is depicted in FIG. 4 at one location in the heat exchanger 304 to what is depicted in FIG. 7 at another location in the same alternative heat exchanger 304. That is, FIG. 7 could represent the way in which the first channels 20 change from their cross-sectional area 96 in FIG. 4 to be of a relatively smaller cross-sectional area 398 at a different location (as evidenced by FIG. 7) in the same heat exchanger 304. By way of further example, the second channels 22 might be unchanged between FIGS. 4 and 7, as is indicated at the numerals 22 and 322. That is, the cross-sectional area indicated at the numeral 96 in FIG. 4 and the cross-sectional area 396 indicated in FIG. 7 might demonstrate that the second channels remain unchanged in size and shape along the distance between FIGS. 4 and 7 and have the same perimeter 62 and 362 along that part of their longitudinal extent, but that in the same distance between FIGS. 4 and 7, the first channels may become relatively smaller. This might be done for any of a variety of reasons, such as the need to avoid thermal shock at the location represented by FIG. 7 or for other reasons. Such thermal shock potentially could be alleviated during startup of the heat exchanger 304 by reducing the relatively cooler flow through the first channels 320 and/or by providing a relatively greater wall thickness as is indicted at the numeral 392 between fluidly isolated channels that might have thermal shock therebetween at some point during the initial operation of the heat exchanger 304. For the same of completeness, it is noted that the relatively smaller first channels 320 in FIG. 7 result in an altered first distance 391 between horizontally adjacent (from the perspective of FIG. 7) first channels 320 that are in fluid communication with one another whereas the first distance 390 between horizontally adjacent second channels 322 is unchanged from the first distance 90 in FIG. 4.

[0066] While the first channels 320 remain in aligned first rows 370 and the second channels 322 remain in aligned second rows 372, this need not necessarily be the case in other embodiments. The adjacent relationships 378A and 378B between one of the first channels 320 and a pair of adjacent channels 320 that are in fluid communication therewith remain of approximately the same orientation, i.e., horizontal, as in FIG. 4 but the first channels 320 are of different distances from one another. The adjacent relationships between such a first channel 320 and the four diagonally adjacent second channels 322 that are fluidly isolated therefrom are indicated by the adjacent relationships 378C, 378D, 378E, and 378F, and these adjacent relationships are of roughly the same diagonal orientation as they were in FIG. 4, although the relative distances are likewise changed due to the smaller cross-sectional area 398 of the first channel 320. Further by way of example, it can be seen that the first channels **320** in FIG. **7** have a wall thickness **376**A between them and the wall surface **368** of the wall **364** whereas the second channels **322** have a relatively greater wall thickness **376**B between them and the wall surface **368**.

[0067] It thus should be apparent that the various channels of the improved compact heat exchanger **304** and other heat exchangers that are described herein and variations thereof can have varying perimeters and cross-sectional areas that can change along their longitudinal lengths. Moreover, such heat exchangers could have three or more legs that are fluidly isolated from another but that are situated in heat transfer relation with each other in one fashion or another. It is also noted that the relative positions of the channels with respect to one another can likewise change along the longitudinal extent of the channels or otherwise. All such changes in the configurations of the channels as a function of position of the longitudinal extent of such channels is again one of a variety of optimization techniques that can be employed to achieve certain heat transfer properties and/or other properties related to the resistance to thermal and magnetic stresses and flow properties and other properties that can be achieved depending upon the needs of the particular application. Other variations will be apparent.

[0068] An improved compact heat exchanger **404** in accordance with a fifth embodiment of the disclosed and claimed concept is depicted in FIGS. **8** and **9** as including a core **406** and as having a schematically depicted header apparatus **408** that may be similar to those mentioned hereinbefore. The core **406** includes a core body **414** having formed therein a plurality of channels **416** that include a plurality of first channels **420**, a plurality of second channels **422**, and an expansion channel **480**.

[0069] The first and second channels **420** and **422** are alternately positioned about the circumference of the expansion channel **480**. While the first channels **420** are in fluid communication with one another, and while the second channels **422** are likewise in fluid communication with one another, the first channels **420** are fluidly isolated from the second channels **422**. Since the first and second channels **420** and **422** are alternately arranged with one another, the wall of the core **406** between each adjacent pair of first and second channels **420** and **422** is likely to experience significant thermal and mechanical stresses due to the temperature difference therebetween. The expansion channel **480** is fluidly isolated from both the first channels **420** and the second channels **422** and is provided in order to permit expansion of the core body **414** into the expansion channel **408** without significantly altering the fluid flow through the first and second channels **420** and **422**.

[0070] It can be seen that the first and second channels **420** and **422** each are of a cross-sectional shape having a perimeter **465** that is of an arcuate shape that is non-oval and is non-circular and is different than the other perimeter shapes mentioned hereinbefore. Rather, the perimeter **465** is multi-lobed to provide a different type of optimization between heat transfer and pressure drop and/or is optimized for other considerations. The first and second channels **420** and **422** each have a cross-sectional area **499** that is equal to one another.

[0071] It thus can be seen that the expansion channel **480** can be provided to alleviate certain thermal or mechanical stresses in the heat exchanger **404** depending upon the needs of the particular application. The expansion channel **480** is formed in situ during the additive manufacturing process mentioned herein. Other expansion channels **480** of different sizes and/or shapes and/or positions can be provided in other embodiments without departing from the present concept.

[0072] It is further noted that the first and second channels **420** and **422** are depicted by themselves, i.e., in the absence of the core **406**, in FIGS. **10** and **11**. It can be seen from FIGS. **10** and **11** that the first and second channels **420** and **422** are formed to have a number of undulations **418**A, **418**B, **418**C, and **418**D along their longitudinal extent. The undulations **418**A, **418**B, **418**C, and **418**D, which may be referred to collectively or individually herein with the numeral **418**, are representative of a change in the direction of elongation of the first and second channels **420** and **422** that gradually occurs, for example, when travelling from the left toward the right or from the right toward the left in FIG. **11**. Such undulations **418** can be of any of a variety of configurations and can be provided for reasons of optimization of heat transfer characteristics and/or for resolution of thermal and mechanical stresses, or for other reasons. Such undulations could be provided in any of the aforementioned heat exchangers that are described elsewhere herein as another way in which performance optimization can be achieved.

[0073] An improved compact heat exchanger **504** in accordance with a sixth embodiment of the disclosed and claimed concept is depicted generally in FIG. **12**. The compact heat exchanger **504** includes a core **506** that includes a plurality of core portions **507**X and **507**Y that are connected together. In the depicted exemplary embodiment, the compact heat exchanger **504** further includes a header apparatus **508** that includes a plurality of header portions **525**X, **525**Y, and **525**Z that are connected together and are connected with the core **506**.

[0074] The compact heat exchanger **504** demonstrates how the cores **6** and the like that are presented elsewhere herein could be connected together to provide a much larger heat exchanger **504** than might be easily capable of manufacture using conventional equipment that performs the aforementioned additive manufacturing process. That is, additive manufacturing equipment that is available at any given time may be capable of producing components that are only of a limited size, and the heat exchanger **504** demonstrates how such components can be scaled to provide a relatively large heat exchanger **504** of a size that is suited to a particular application and that perhaps could not be manufactured during a single additive manufacturing operation.

[0075] The exemplary core portions **507**X and **507**Y are depicted as having relatively straight and elongated channel portions **517** (core portion **507**X) or as having channel portions **517** that include one or more bends (core portion **507**Y). Such channel portions **517** can be connected with one another end-to-end via sintering or other diffusion bonding operations as needed to provide desired comprehensive flow channels **516** that are formed from the various core portions **507**X and **507**Y. That is, the exemplary comprehensive channel **516** is depicted in FIG. **12** as including a plurality of channel portions **517** that are connected end-to-end to form the channel **516**.

[0076] The header apparatus **508** includes a plurality of headers indicated at the numeral **524**A, **524**B, **524**C, and **524**D, which may be referred to collectively or individually herein with the numeral **524**. The various headers **524** are formed of various combinations of the header portions

525X, **525**Y, and **525**Z as needed to achieve the desired performance characteristics that are suited to the application of the heat exchanger **504**. It is expressly noted that the core **406** that is depicted in FIGS. **8** and **9** or any of the other cores mentioned elsewhere herein or variations thereof could be employed as any one or more of the core portions **507**X and **507**Y that are schematically depicted in FIG. **12** depending upon the needs of the particular application. Moreover, any of the interrelationships between positions, sizes, shapes, and the like of the flow channels can be incorporated into the heat exchanger **504** as needed for optimization or for other reasons.

[0077] It thus can be seen that the various compact heat exchangers presented herein and the components thereof can have any of a wide variety of features and interrelationships among the various components thereof to provide needed optimization for various applications. Optimization can be provided on the basis of fluid flow performance and/or on the basis of heat transfer performance and/or on the basis of resistance to thermal and/or mechanical stresses, and/or according to other bases for optimization. Such optimization is highly cost effective given the additive manufacturing process described above. The various features and interrelationships that are described herein can be combined in any fashion without departing from the present concept.

[0078] While specific embodiments of the invention have been described in detail, it will be appreciated by those skilled in the art that various modifications and alternatives to those details could be developed in light of the overall teachings of the disclosure. Accordingly, the particular embodiments disclosed are meant to be illustrative only and not limiting as to the scope of the invention which is to be given the full breadth of the appended claims and any and all equivalents thereof.

What is claimed is:

1. A compact heat exchanger comprising:

a plurality of layers affixed to one another and together forming a core and a header apparatus;

the core having formed therein a plurality of channels, the plurality of channels comprising a number of first channels and a number of second channels, at least a portion of the number of first channels being position for being in heat transfer relation with at least a portion of the number of second channels;

the header apparatus comprising at least a first header that is in fluid communication with at least some of the channels of the number of channels;

the at least first header having a channel end and a connection end, the channel end being situated adjacent the core and including a number of flow connections that are in direct fluid communication with the at least some of the channels, the connection end having an opening that is structured to be connected in fluid communication with another flow structure, the at least one header comprising a flow passage that extends between the channel end and connection end and that enables fluid communication between the number of flow connections and the opening; and

at least one of the layers of the plurality of layers being at least one of:

a layer that comprises a portion of but less than the entirety of the at least first header and that has formed therein at least a portion of the flow passage,

a layer that comprises at least a portion of the core having formed therein at least a portion of a first channel and at least a portion of a second channel that are fluidly isolated from one another, and

a layer that comprises at least a portion of the core having formed therein at least a portion of a channel of the plurality of channels and that further comprises a portion of the at least first header and that has formed therein at least a portion of the flow passage.

2. The compact heat exchanger of claim **1** wherein at least some of the channels of the plurality of channels each have an arcuate perimeter that is of a shape that is non-circular.

3. The compact heat exchanger of claim **2** wherein another channel that is situated adjacent a channel of the at least some of the channels has another arcuate perimeter that is of another shape different than the shape.

4. The compact heat exchanger of claim **1** wherein the number of first channels are in fluid communication with one another and wherein the number of second channels are in fluid communication with one another, the number of first channels being fluidly isolated from the number of second channels, and wherein at least one first channel of the number of first channels is situated adjacent at least three other first channels of the number of first channels and is further situated adjacent at least three second channels of the number of second channels.

5. The compact heat exchanger of claim **1** wherein the core comprises a wall having situated at a side thereof both a first channel of the number of first channels and a second channel of the number of second channels and having at another side thereof a wall surface that faces generally away from the number of first channels and the number of second channels, the minimum thickness of the wall between the wall surface and the first channel being different than the minimum thickness of the wall between the wall surface and the second channel.

6. The compact heat exchanger of claim **1** wherein the core comprises a plurality of core portions affixed together, at least some of the core portions of the plurality of core portions each having formed therein a plurality of channel portions, the plurality of channels portions comprising a number of first channel portions and a number of second channel portions, a first channel portion of the number of first channel portions of each of a plurality quantity of the plurality of core portions being connected together end-to-end to form at least a portion of a first channel of the number of first channels, a second channel portion of the number of second channel portions of each of the plurality quantity of the plurality of core portions being connected together end-to-end to form at least a portion of a second channel of the number of second channels.

7. The compact heat exchanger of claim **1** wherein the at least first header comprises a number of flow directors, and wherein a flow passage of the number of flow passages comprises a plurality of flow passage portions that together extend between the opening and a corresponding channel of the at least some of the channels and that permit fluid flow therebetween, at least a first flow director of the number of flow directors being situated adjacent the core and between a pair of first channels of the number of first channels, the at least first flow director having an external surface, a portion of the external surface forming at least a part of a flow passage portion of the plurality of flow passage portions that is in fluid communication with a first channel of the pair of first channels

8. The compact heat exchanger of claim **7** wherein another portion of the external surface forms at least a part of another flow passage portion of the plurality of flow passage portions of another flow passage of the number of flow passages that is in direct fluid communication with another first channel of the pair of first channels.

9. The compact heat exchanger of claim **1** wherein the at least first header is a first inlet header, and wherein the header apparatus further comprises a first outlet header;

the first inlet header being in fluid communication with at least some of the number of first channels at an inlet end thereof;

the first outlet header being in fluid communication with the at least some of the number of first channels at an outlet end thereof; and

the at least one of the layers being a layer that comprises a portion of the core having formed therein at least a portion of a first channel of the number of first channels, and that further comprises a portion of the first inlet header and a portion of the first outlet header in fluid communication with the at least portion of the first channel.

10. The compact heat exchanger of claim **9** wherein the header apparatus further comprises a second inlet header and a second outlet header, the second inlet header being in fluid communication with at least some of the number of second channels at an inlet end thereof, and the second outlet header being in fluid communication with the at least some of the number of first channels at an outlet end thereof.

11. The compact heat exchanger of claim **1** wherein at least some of the channels of the plurality of channels are elongated along a direction of elongation and include a number of undulations along the direction of elongation.

12. The compact heat exchanger of claim **1** wherein the core comprises a wall that is situated between a pair of adjacent channels of the plurality of channels, wherein the wall is of a thickness at a location on the core whereby the pair of adjacent channels are separated apart by a distance that is equal to the thickness, and wherein the wall is of another thickness at another location on the core spaced from the location whereby the pair of adjacent channels are separated apart by another distance that is equal to the another thickness, the thickness and the another thickness being unequal.

13. The compact heat exchanger of claim **1** wherein the number of first channels are in fluid communication with one another, wherein the number of second channels are in fluid communication with one another, and wherein the plurality of channels further comprise a number of additional channels that are fluidly isolated from the number of first channels and that are fluidly isolated from the number of second channels.

14. The compact heat exchanger of claim **13** wherein the number of additional channels comprise an additional channel that is situated adjacent at least one of a first channel of the number of first channels and a second channel of the number of second channels.

15. The compact heat exchanger of claim **14** wherein the core has formed therein an opening that extends between the additional channel and the exterior of the core.

16. The compact heat exchanger of claim **14** wherein the additional channel is situated adjacent a plurality of first channels of the number of first channels and is further situated adjacent a plurality of second channels of the number of second channels.

17. The compact heat exchanger of claim **13** wherein the core further comprises a number of heaters that are received in the number of additional channels and that are structured to be operable to preheat the compact heat exchanger.

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