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

(11) EP 3 247 966 B1

# (12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
**04.12.2019 Bulletin 2019/49**

(21) Application number: **16706692.7**

(22) Date of filing: **15.01.2016**

(51) Int Cl.:
***F28F 21/06*** *(2006.01)* ***F28D 9/00*** *(2006.01)*

(86) International application number:
**PCT/US2016/013617**

(87) International publication number:
**WO 2016/118417 (28.07.2016 Gazette 2016/30)**

## (54) POLYMER FILM HEAT EXCHANGER WITH INTEGRAL MANIFOLDS

POLYMERSCHICHT-WÄRMETAUSCHER MIT INTEGRIERTEN VERTEILERN

ÉCHANGEUR THERMIQUE À FILM POLYMÈRE, POURVU DE COLLECTEURS INTÉGRÉS

(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**

(30) Priority: **20.01.2015 US 201514600927**

(43) Date of publication of application:
**29.11.2017 Bulletin 2017/48**

(73) Proprietor: **Energy & Environmental Research Center Foundation**
**Grand Forks, North Dakota 58202 (US)**

(72) Inventors:
- **MARTIN, Christopher Lee**
  **Grand Forks, North Dakota 58201 (US)**
- **DUNHAM, Grant Edward**
  **Grand Forks, North Dakota 58201 (US)**

(74) Representative: **Walker, Ross Thomson**
**Forresters IP LLP**
**Skygarden**
**Erika-Mann-Strasse 11**
**80636 München (DE)**

(56) References cited:
**EP-A1- 2 508 832**
**DE-A1- 3 641 458**
**DE-U1-202010 007 615**
**US-A- 3 585 131**
**US-A- 5 862 856**



EP 3 247 966 B1

## Description

CLAIM OF PRIORITY

**[0001]** This application claims the benefit of U.S. Patent Application Serial No. 14/600,927, titled POLYMER FILM HEAT EXCHANGER WITH INTEGRAL FLUID DISTRIBUTION MANIFOLDS AND METHOD, filed on January 20, 2015, invented by Christopher Lee Martin and Grant Edward Dunham, the benefit of priority of which is claimed hereby, and which is incorporated by reference herein in its entirety.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

**[0002]** This invention was made with government support under Energy Cooperative Agreement No. DE-AR0000309 awarded by the Advanced Research Projects Agency-Energy. The government has certain rights in the invention.

BACKGROUND

**[0003]** Polymer-based heat exchangers offer unique benefits to end users including low-cost material of construction, resistance to fouling due to smooth surfaces, and generally excellent corrosion resistance. However, polymers have relatively poor thermal conductivity, and it is not practical to construct a polymer heat exchanger based on conventional metal heat exchanger design principles. In order for the polymers to have sufficient mechanical strength for conventional metal heat exchanger designs, the wall thicknesses would be so thick as to hinder effective heat transfer.

**[0004]** Several designs have been proposed that adapt to the strength limitations of thin polymer interfaces, but none have resulted in a design simplicity that is required to dramatically lower costs. As a result, polymer-based heat exchangers are today limited to relatively high value applications that require the inertness that polymers can provide, e.g., pharmaceutical processing, healthcare products, and corrosive fluid processing.

**[0005]** US 4,411,310 and US 4,744,414 both refer to the use of polymer films to separate flow channels and serve as an effective heat exchanger surface. However, each of these examples also requires additional non-film components to complete the fluid circuits. US 4,411,310 refers to a separate molded manifold to which the polymer film flow channels are bonded in order to distribute the heat-transfer fluids to the appropriate flow channels. Similarly, US 4,744,414 refers to molded spacers between the polymer layers to form the flow channels and provide the fluid distribution function. EP2508832 A1 relates to a heat exchanger having rigid or semi-rigid films that maintain a single shape in a single layer or with a non-pressurised fluid.

SUMMARY OF THE INVENTION

**[0006]** A polymer film heat exchanger with integral fluid distribution manifolds. The present invention provides a device according to claim 1 and an associated method of manufacturing the device according to claim 10. Any subject matter described herein that does not fall within the scope of the claims is provided for information purposes only.

BRIEF DESCRIPTION OF THE DRAWINGS

**[0007]** In the drawings, which are not necessarily drawn to scale, like numerals may describe similar components in different views. Like numerals having different letter suffixes may represent different instances of similar components. The drawings illustrate generally, by way of example, but not by way of limitation, various embodiments discussed in the present document.

FIG. 1 illustrates a perspective view of a heat exchanger assembly, in accordance with at least one example of the present subject matter.

FIG. 2 illustrates a top view of a heat exchanger assembly, in accordance with at least one example of the present subject matter.

FIG. 3 illustrates a side view of a heat exchanger assembly, in accordance with at least one example of the present subject matter.

FIG. 4 illustrates a bonding pattern schematic of a film stack, in accordance with at least one example of the present subject matter.

FIG. 5A illustrates cross section 5A-5A of the film stack of FIG. 4, in accordance with at least one example of the present subject matter.

FIG. 5B illustrates cross section 5B-5B of the film stack of FIG. 4, in accordance with at least one example of the present subject matter.

FIG. 5C illustrates cross section 5C-5C of the film stack of FIG. 4, in accordance with at least one example of the present subject matter.

FIG. 6 illustrates a schematic drawing of cross section 5A-5A of FIG. 4, in accordance with at least one example of the present subject matter.

FIG. 7 illustrates a schematic drawing of cross section 5B-5B of FIG. 4, in accordance with at least one example of the present subject matter.

FIG. 8 illustrates a schematic drawing of cross section 5C-5C of FIG. 4, in accordance with at least one example of the present subject matter.

FIG. 9 illustrates a flow chart of a method, in accordance with at least one example of the present subject matter.

DETAILED DESCRIPTION

**[0008]** A heat exchanger operates to transfer heat from one fluid to another. The fluid can be liquid, vapor, or gas or a combination of the matter states. Hygroscopic fluids can be extremely useful in certain heat exchanger applications to limit water use. Hygroscopic fluids can be extremely corrosive and polymers can provide excellent resistance to corrosive fluids.

**[0009]** There is a need for a polymer heat exchanger that is low cost in construction and less complicated than previous heat exchangers. Described herein is a heat exchanger that includes a stack of film layers (film stack). The film stack can include alternating fluid passages that are separate from each other. Each fluid passage can include an input port and an output port and the input ports and output ports can be arranged so that the heat exchanger operates on a counter flow basis; fluid A flows in one direction and fluid B flows in the opposite direction.

**[0010]** The entire fluid circuit for both heat-transfer fluids, including the fluid distribution manifolds, can be formed using only a flexible polymer film. Forming integral manifolds out of the polymer film itself eliminates the need for additional pieces to be added to the heat exchanger.

**[0011]** The heat exchanger described herein formed from a stack of flexible polymer film sheets forms a parallel plate heat exchanger having alternating layers of flow channels. Fluid distribution can be accomplished by selectively bonding together film layers around flow channel apertures in an alternating manner so that a single fluid connection port can be only in fluid communication with alternating flow channels associated with only one of the heat exchange fluids. Dimensions of the flow channels can be regulated by regulating fluid pressures applied to one or more of the heat exchanger fluids. The entire assembly can be restrained from overexpansion by external rigid plates that sandwich the polymer film stack.

**[0012]** To further illustrate the heat exchanger and method disclosed herein, a non-limiting list of examples is provided here:

**[0013]** In Example 1, a device can comprise: a plurality of polymer films including a first film adjacent a second film and including a third film adjacent the second film, the plurality of polymer films in stacked alignment and having a stack axis normal to a plane of the plurality of polymer films, wherein the first film is bonded to the second film with a first bond having a first pattern configured to form a first channel between the first film and the second film, and further wherein the second film is bonded to the third film with a second bond having a second pattern configured to form a second channel between the second film and the third film, and further including a first pair of ports fluidly coupled to the first channel and including a second pair of ports fluidly coupled to the second channel, wherein the first pair of ports and the second pair of ports have port axes aligned substantially parallel with the stack axis.

**[0014]** In Example 2, the device of Example 1 can optionally be configured such that the third film is bonded to a fourth film with a third bond, the third bond having the first pattern and wherein the first channel is fluidly coupled to a region bound by the third film and the fourth film.

**[0015]** In Example 3, the device of Example 2 can optionally be configured such that the fourth film is bonded to a fifth film with a fourth bond, the fourth bond having the second pattern and wherein the second channel is fluidly coupled to a region bound by the fourth film and the fifth film.

**[0016]** In Example 4, the device of any one or any combination of Examples 1-3 can optionally be configured such that the first channel is bound by the first bond and wherein the second channel is bound by the second bond.

**[0017]** In Example 5, the device of any one or any combination of Examples 1-4 can optionally be configured such that the first pair of ports and the second pair of ports are on a common side of the plurality of polymer films.

**[0018]** In Example 6, the device of any one or any combination of Examples 1-5 can optionally be configured such that the polymer films of the plurality of polymer films have a substantially rectangular profile and wherein the first pair of ports includes a first input port and includes a first output port and wherein the first input port and the first output port are aligned on a common diagonal determined by the profile.

**[0019]** In Example 7, the device of any one or any combination of Examples 1-6 can optionally be configured such that at least one of the first bond and the second bond includes at least one of a thermal joint, a weld joint, and an adhesive joint.

**[0020]** In Example 8, the device of any one or any combination of Examples 1-7 can optionally be configured such that the first channel is fluidly isolated from the second channel.

**[0021]** In Example 9, the device of any one or any combination of Examples 1-8 can optionally be configured to further include a first reinforcement plate coupled to a first selected polymer film of the plurality of polymer films.

**[0022]** In Example 10, the device of Example 9 can optionally be configured to further include a second reinforcement plate coupled to a second selected polymer film of the plurality of polymer films.

**[0023]** In Example 11, the device of Example 10 can optionally be configured to further include at least one spacer coupled to the first reinforcement plate and coupled to the second reinforcement plate, wherein the at least one spacer is configured to retain the first reinforcement plate and the second reinforcement plate in fixed alignment and at a predetermined distance apart.

**[0024]** In Example 12, the device of any one or any combination of Examples 1-11 can optionally be configured such that the first film and the second film have a dimension in common.

**[0025]** In Example 13, the device of any one or any combination of Examples 1-12 can optionally be configured such that the first film, the second film, and the third film have an aperture in common.

**[0026]** In Example 14, a method can comprise forming a first bond coupling a first film and a second film, the first bond having a first bond pattern, the first film and the second film in stacked alignment and having a first channel therebetween; forming a second bond coupling the second film and a third film, the second bond having a second bond pattern, the second film and the third film in stacked alignment and having a second channel therebetween, the second channel fluidly independent of the first channel; forming a first pair of ports in the first film, the first pair of ports in fluid communication with the first channel; and forming a second pair of ports in the third film, the second pair of ports in fluid communication with the second channel.

**[0027]** In Example 15, the method of Example 14 can optionally be configured to further include forming a third bond coupling the third film and a fourth film, the third bond having the first bond pattern, the third film and the fourth film in stacked alignment and wherein the first channel is fluidly coupled to a region bound by the third film and the fourth film.

**[0028]** In Example 16, the method of Example 15 can optionally be configured to further include forming a fourth bond coupling the fourth film and a fifth film, the fourth bond having the second bond pattern, the fourth film and the fifth film in stacked alignment and wherein the second channel is fluidly coupled to a region bound by the fourth film and the fifth film.

**[0029]** In Example 17, the method of any one or any combination of Examples 14-16 can optionally be configured such that forming the first pair of ports and forming the second pair of ports includes forming on a common side of the films.

**[0030]** In Example 18, the method of any one or any combination of Examples 14-17 can optionally be configured such that the first film, the second film, and the third film have a substantially rectangular profile and wherein forming the first pair of ports includes forming a first input port and includes forming a first output port and wherein the first input port and the first output port are aligned on a common diagonal determined by the profile.

**[0031]** In Example 19, the method of any one or any combination of Examples 14-18 can optionally be configured such that at least one of forming the first bond and forming the second bond includes forming at least one of a thermal joint, a weld joint, and an adhesive joint.

**[0032]** In Example 20, the method of any one or any combination of Examples 14-19 can optionally be configured to further include affixing a first reinforcement plate to the first film.

**[0033]** In Example 21, the method of Example 20 can optionally be configured to further include affixing a second reinforcement plate coupled to a film.

**[0034]** In Example 22, the method of Example 21 can optionally be configured to further include providing at least one spacer coupled to the first reinforcement plate and coupled to the second reinforcement plate, wherein the at least one spacer is configured to retain the first reinforcement plate and the second reinforcement plate in fixed alignment and at a predetermined distance apart.

**[0035]** In Example 23, the device and method of any one or any combination of Examples 1-22 can optionally be configured such that all elements, operations, or other options recited are available to use or select from.

**[0036]** FIG. 1 illustrates a heat exchanger assembly 15. The heat exchanger assembly 15 can include a film stack 1 sandwiched between a first reinforcement plate 16 and a second reinforcement plate 18. The film stack 1 can be formed from a plurality of film layers 20 layered one atop the other. In this application, the term film layer 20 can refer to any of the film layers in the film stack 1. The film layers 20 can be formed of a polymer, rubber, plastic, metal or any combination or composite of materials that can contain a fluid. The film layers 20 are flexible. The film layers 20 are in sheet form. The first and second reinforcement plates 16, 18 can be formed from a rigid material and can limit the expansion of the film stack. The first and second reinforcement plates 16, 18 can also provide a rigid structure that can be used for attachment. The first reinforcement plate 16 and the second reinforcement plate 18 can be separated by spacers 4. The heat exchanger assembly 15 and film stack 1 is illustrated as planar and rectangular. In an example, the heat exchanger assembly 15 and/or film stack 1 can be shaped as any regular or irregular polygon, circular, or as having both straight and curvilinear portions. In an example, the heat exchanger assembly 15 and/or film stack 1 can be all or partially non-planar, such as including arched, bowed, or curvilinear portions. The film stack 1 can include at least two separate fluid passages, such as a Fluid A flow passage 22 and a Fluid B flow passage 24. The fluid flow passages can be described as any portion of the heat exchanger to which a fluid has access. The Fluid A flow passage 22 can be associated with a Fluid A input port 5 and a Fluid A output port 6. The Fluid B flow passage 24 can be associated with a Fluid B input port 7 and a Fluid B output port 8. The ports can be described as the outer opening of the fluid passage. The ports can include fluid connections 30 that can be connected to the film stack 1 and extend through the first or second reinforcement plate 16, 18. The fluid connections 30 can be the fittings, tubings, piping, or fluid connectors that can connect to a continuation of the fluid passage or an additional fluid passage.

**[0037]** FIG. 2 illustrates a top view of a heat exchanger assembly 15, in accordance with at least one example of the present subject matter. The heat exchanger assembly 15, as illustrated, can be configured for two fluids, Fluid A and Fluid B. Each fluid can be liquid, vapor, or gas or a combination of the matter states. A heat exchanger assembly 15 can be used having more than two fluids. The heat exchanger assembly 15 can be configured for counterflow flow heat exchange, whereby Fluid A can enter Fluid A input port 5 and can exit Fluid A output port 6 and Fluid B can enter Fluid B input port 7 and can exit Fluid B output port 8. While this configuration is preferred for effective heat transfer, it is also recognized that a parallel flow configuration is also possible. The film stack 1 can include a substantially rectangular profile 34. The Fluid A input port 5 and the Fluid A output port 6 can be aligned on a first common diagonal 36 of the rectangular profile 34. The Fluid B input port 7 and the Fluid B output port 8 can be aligned on a second common diagonal 38 of the rectangular profile 34. The diagonal orientation shown encourages counterflow heat exchange between Fluids A and B. The input and output ports can be bonded to the film stack 1. (see FIGS. 5A and 5C). In another example, the film stack 1 can be bonded and sealed to the first or second reinforcement plates 16, 18 and the fluid connections 30 (see FIG. 1) can be bonded and sealed to the first or second reinforcement plates 16, 18.

**[0038]** The heat exchanger assembly 15 is illustrated as having the input and output ports extending through one reinforcement plate (see FIG. 1), but any configuration of porting can be used, such as having both input ports extending through one plate and both output ports extending through the opposite plate, or as having the ports of Fluid A extending through one plate and the ports of Fluid B extending through the opposite plate. The heat exchanger assembly 15 can be configured with one of the ports extending through one plate and the three other ports extending through the other plate.

**[0039]** An outer perimeter 41 of the film stack 1 is shown as located inwardly from the spacers 4. The spacers 4 can include a bore 13 and be positioned between corresponding holes 17 in the reinforcement plates 16, 18. A fastener 42 (such as a threaded bolt or threadless rivet) can extend through the bore 13 and holes 17 and secure the first reinforcement plate 16 to the second reinforcement plate 18. The spacers 4 and fasteners 42 can retain the reinforcement plates in fixed alignment and a predetermined distance apart. In another example, one or more spacers 4 can be integral with the first reinforcement plate 16, the second reinforcement plate 18, or both plates.

**[0040]** FIG. 3 illustrates a side view of a heat exchanger assembly 15, in accordance with at least one example of the present heat exchanger. The film stack 1 can be sandwiched between the first reinforcement plate 16 and the second reinforcement plate 18. The spacers 4 can provide a predetermined distance 44 that the film stack 1 can be allowed to expand when under fluid pressure. The reinforcement plates 16, 18 can prevent the film stack 1 from over-expanding. Although the film stack 1 is illustrated with approximately 12 film layers 20, any number of three or more film layers 20 can be used in the heat exchanger assembly 15.

**[0041]** FIG. 4 illustrates a bonding pattern schematic of a film stack 1, in accordance with at least one example of the present subject matter. In the film stack 1, film layers 20 (see FIG. 3) can be stacked one upon the other to provide a desired thickness for the heat exchanger assembly 15. Each film layer 20 can be identical or very similar in size and shape and can include a Fluid A input aperture 46, a Fluid A output aperture 48, a Fluid B input aperture 50, and a Fluid B output aperture 52. The Fluid A input aperture 46 and the Fluid A output aperture 48 of each layer can be fluidly coupled to the Fluid A flow passage 22. The Fluid B input aperture 50 and the Fluid B output aperture 52 of each layer can be fluidly coupled to the Fluid B flow passage 24 (see FIG. 1).

**[0042]** FIG. 4 illustrates two bonding patterns, a first bonding pattern 10, and a second bonding pattern 9. One of the first bonding pattern 10 or the second bonding pattern 9 can be used on the first side of the film layer 20. The bonding pattern not used on the first side of the film layer 20 can be used on the opposite side of the film layer 20. In the first bonding pattern 10, a first pattern bond perimeter 40A can be bonded between layers. In the second bonding pattern 9 a second pattern bond perimeter 40B can be bonded between layers. Bonding includes at least one of a thermal joint, a weld joint or an adhesive joint. The bonding forms a fluid tight seal that separates fluids from intermixing and prevents leakages. The first bonding pattern 10 includes bonding around the Fluid A input aperture 46 and the Fluid A output aperture 48, such that Fluid B in a flow channel does not intermix with Fluid A at the Fluid A input aperture 46 and the Fluid A output aperture 48. The second bonding pattern 9 includes bonding around the Fluid B input aperture 50 and the Fluid B output aperture 52, such that Fluid A in a flow channel does not intermix with Fluid B at the Fluid B input aperture 50 and the Fluid B output aperture 52.

**[0043]** FIG. 5A illustrates a cross section 5A-5A of the film stack 1 of FIG. 4, in accordance with at least one example of the present subject matter. The cross section 5A-5A can include the Fluid A input port 5 and the Fluid B output port 8. For description purposes, beginning from a first side 60 of the film stack 1, a first film 62A can be bonded to a second film 62B by a first bond 66A having a first bonding pattern 10 (see FIG. 4). The first bonding pattern 10 does not include any bonding between the first film 62A and the second film 62B in a region of the Fluid B output aperture 52 of the second film 62B. A first channel 70A can be formed between the first film 62A and the second film 62B. The first bond 66A can bond the Fluid A input aperture 46 of the second film 62B to the first film 62A so Fluid A and Fluid B cannot mix at the Fluid A input aperture 46. The first channel 70A can be fluidly connected to the Fluid B flow passage 24. In the example shown, the first film 62A has no fluid apertures and has no bonding on a bottom surface 72. In an example, the first film 62A could have fluid apertures that are bonded to the reinforcement plate.

**[0044]** In an example, second film 62B is bonded on its bottom surface 56A with the first bond pattern 10 to the first film 62A. The second film 62B is bonded on its upper surface 57 with the second bond pattern 9 to the bottom surface 56B third film 62C. For example, when a film layer 20 is bonded to an adjacent film layer 20, one set of input/output apertures can have a fluid tight bond between the layers, while the other set of input/output apertures can remain unbonded between the two layers. In conjunction with the first pattern bond perimeter 40A or the second pattern bond perimeter 40B , such bonding at the apertures can create a flow channel 58 for either Fluid A or Fluid B, depending on whether the first bonding pattern 10 or the second bonding pattern 9 is used between the two layers. When the bonding pattern around a fluid aperture is bonded, and two adjacent film layers are bonded together at the fluid aperture, then no fluid at that fluid aperture can get between those two film layers. Conversely, when the bond pattern is such that two adjacent film layers are not bonded together at a fluid aperture, then fluid from the fluid aperture can enter between the two film layers and form a flow channel 58.

**[0045]** By alternating the first bonding pattern 10 and the second bonding pattern 9, the bonding patterns can be reversed, meaning that the first bonding pattern 10 can be bonded to a layer above, and the second bonding pattern 9 can be bonded to the layer below. This alternating pattern can be repeated until a desired number of flow channels 58 are reached. Each film layer 20 can be identical in dimensions and hole placements; the orientation of the bonding patterns can change from layer to layer, in other words the first bonding pattern 10 can be between one set of adjacent layers, the second bonding pattern 9 can be between the next set of adjacent layers and so on.

**[0046]** A third film 62C can be located over the second film 62B. The second film 62B can be bonded to the third film 62C by a second bond 66B having a second bonding pattern 9. The second bond 66B having the second bonding pattern 9 does not include any bonding between the second film 62B and the third film 62C in the region of the Fluid A input apertures 46 of the second and third films 62B, 62C. A second channel 70B can be formed between the second film 62B and the third film 62C. The second channel 70B can be fluidly connected to the Fluid A flow passage 22. The second bond 66B bonds the Fluid B output aperture 52 of the second film 62B to the Fluid B output aperture 52 of the third film 62C so Fluid A and Fluid B cannot mix at the Fluid B output aperture 52.

**[0047]** A fourth film 62D can be located over the third film 62C. A third bond 66C having the first bonding pattern 10 can bond the third film 62C to the fourth film 62D. The third bond 66C having the first bonding pattern 10 does not include any bonding between the third film 62C and the fourth film 62D in the region of the Fluid B output aperture 52 of the third film 62C and the fourth film 62D. A third channel 70C can be formed between the third film 62C and the fourth film 62D. The third channel 70C can be fluidly connected to the Fluid B flow passage 24. The third bond 66C bonds the Fluid A input aperture 46 of the third film 62C to the fourth film 62D so Fluid A and Fluid B cannot mix at the Fluid A input aperture 46. There is a fluid passage 84 between the first pattern bond perimeter 40A of the third bond 66C and the Fluid A input aperture 46. This fluid passage 84 is a portion of the third channel 70C and can also be seen from the top view of FIG. 4. Such a fluid passage 84 can be found in all channels formed by the first bonding pattern 10.

**[0048]** A fifth film 62E can be located over the fourth film 62D. The fifth film 62E can be bonded to the fourth film 62D by a fourth bond 66D having the second bonding pattern 9. The fourth bond 66D having the second bonding pattern 9 does not include any bonding between the fourth film 62D and the fifth film 62E in the region of the Fluid A input aperture 46 of the fourth and fifth films 62D, 62E. A fourth channel 70D can be formed between the fourth film 62D and the fifth film 62E. The fourth channel 70D can be fluidly connected to the Fluid A flow passage 22. The fourth bond 66D bonds the Fluid B output aperture 52 of the fourth film 62D to the Fluid B output aperture 52 of the fifth film 62E so Fluid A and Fluid B cannot mix at the Fluid B output aperture 52.

**[0049]** The alternating bonding of the first bonding pattern 10 and the second bonding pattern 9 to additional film layers 20 can also create a fifth channel 70E, a sixth channel 70F, a seventh channel 70G, an eighth channel 70H and a ninth channel 70J. The fifth, seventh and ninth channels 70E, 70G, 70J can be fluidly connected to the Fluid B flow passage 24. The sixth and eighth channels 70F, 70H can be fluidly connected to the Fluid A flow passage 22.

**[0050]** The film layers 20 of the film stack 1 can be stacked in a direction that is substantially normal to the plane of each film layer 20. The connection of the channels to a fluid flow passage, such as the connection of the first, third, fifth, seventh and ninth channels 70A, 70C, 70E, 70G, 70J to the Fluid B flow passage 24 can form a Fluid B port manifold 25 at both the Fluid B input port 7 (see also FIG. 5C) and the Fluid B output port 8. The Fluid B port manifold 25 can include a port axis 51 that is substantially perpendicular to the plane of the film stack 1. In a similar manner a Fluid A port manifold 23 can be formed at both the Fluid A input port 5 and the Fluid A output port 6 (see also FIG. 5C).

**[0051]** FIG. 5B illustrates a cross section 5B-5B of the film stack of FIG. 4, in accordance with at least one example of the present heat exchanger. Cross section 5B-5B is located near the middle of the film stack 1 and does not intersect any of the apertures 46, 48, 50, 52. The nine channels can be formed by alternating application of the first bonding pattern 10 and the second bonding pattern 9. The Fluid B flow passage 24 is fluidly coupled to the first channel 70A, the third channel 70C, the fifth channel 70E, the seventh channel 70G and the ninth channel 70J. The Fluid A flow passage 22 is fluidly coupled to the second channel 70B, the fourth channel 70D, the sixth channel 70F, and the eighth channel 70H (see FIG. 5A). As illustrated, there can be a great amount of surface area contact between channels flowing Fluid A and channels flowing Fluid B. The heat exchanger assembly 15 can be formed with as many or few flow channels as desired; simply by adding or subtracting film layers and changing the spacer 4 length and fastener 42 length if desired (see FIG. 3).

**[0052]** FIG. 5C illustrates a cross section 5C-5C of the film stack of FIG. 4, in accordance with at least one example of the present subject matter. Cross section 5C-5C can include the Fluid B input port 7 and the Fluid A output port 6. Fluid connections 30 can be bonded to the outer surface 102 of a second side 104 of the film stack 1 at the flow passages 22, 24. The film layers 20 are bonded in the same manner as in FIG. 5A with alternating bonding patterns that form the first channel 70A, the third channel 70C, the fifth channel 70E, the seventh channel 70G and the ninth channel 70J fluidly coupled to the Fluid B flow passage 24. The Fluid A flow passage 22 is fluidly coupled to the second channel 70B, the fourth channel 70D, the sixth channel 70F, and the eighth channel 70H. FIG 4 and FIGS. 5A-C illustrate an example of the first bonding pattern 10 and the second bonding pattern 9.

**[0053]** The film layer 20 has a flattened sheet-like form. When containing a fluid, such as a pressurized fluid, the flow channels, such as channels 70A-H and 70J can expand the film layer 20 into a three dimensional form as shown. Additional bonds not needed for fluid channel sealing can be included between adjacent film layers to encourage uniform expansion of film layer 20 into a three dimensional form.

**[0054]** FIG. 6 illustrates an example of a schematic drawing of cross section 5A-5A of FIG. 4 (having fewer layers than FIG. 5A) and includes a first reinforcement plate 16 and a second reinforcement plate 18. The bond segments of the first bond 66A, the second bond 66B, the third bond 66C, and the fourth bond 66D (parts of continuous bond) that are shown directly across from each other represent a sealed bond between layers. A first film 62A can be directly adjacent a first reinforcement plate 16. The first film 62A can be configured without flow passage apertures. The first film 62A can remain unbonded to the first reinforcement plate 16 or can be bonded to the first reinforcement plate 16. The cross section 5A-5A can include the Fluid A input port 5 and the Fluid B output port 8. Beginning from a first side 60 of the film stack 1, a first film 62A can be bonded to a second film 62B by a first bond 66A having a first bonding pattern 10. The first bonding pattern 10 does not include any bonding between the first film 62A and the second film 62B in the region of the Fluid B output aperture 52 of the second film 62B. A first channel 70A can be formed between the first film 62A and the second film 62B. The first bond 66A bonds the Fluid A input aperture 46 of the second film 62B to the first film 62A so Fluid A and Fluid B cannot mix at the Fluid A input aperture 46. The first channel 70A can be fluidly connected to the Fluid B flow passage 24. The circle depicted at the end of the lines showing the Fluid B flow passage 24 illustrates that it is not at a flow through point in the channel, such as in the first channel 70A where bonds 66A block the fluid from combining with the Fluid A flow passage 22. This pattern is repeated in FIG. 6 and FIG. 8 for the Fluid B flow passage 24 and the Fluid A flow passage 22.

**[0055]** A third film 62C can be located over the second film 62B. The second film 62B can be bonded to the third film 62C by a second bond 66B having a second bonding pattern 9. The second bond 66B having the second bonding pattern 9 does not include any bonding between the second film 62B and the third film 62C in the region of the Fluid A input aperture 46 of the second and third films 62B, 62C. A second channel 70B can be formed between the second film 62B and the third film 62C. The second channel 70B can be fluidly connected to the Fluid A flow passage 22. The second bond 66B bonds the Fluid B output aperture 52 of the second film 62B to the Fluid B output aperture 52 of the third film 62C so Fluid A and Fluid B cannot mix at the Fluid B output aperture 52.

**[0056]** A fourth film 62D can be located over the third film 62C. A third bond 66C having the first bonding pattern 10 can bond the third film 62C to the fourth film 62D. The third bond 66C having the first bonding pattern 10 does not include any bonding between the third film 62C and the fourth film 62D in the region of the Fluid B output aperture 52 of the third film 62C and the fourth film 62D. A third channel 70C can be formed between the third film 62C and the fourth film 62D. The third channel 70C can be fluidly connected to the Fluid B flow passage 24. The third bond 66C bonds the Fluid A input aperture 46 of the third film 62C to the fourth film 62D so Fluid A and Fluid B cannot mix at the Fluid A input aperture 46. The fluid passage 84 described previously is shown on channels having the first bonding pattern 10. In FIG. 6, fluid passage 84 is shown as a circle for illustrative purposes only. The circle represents a fluid passage 84 between the perimeter bond 40A and the bond at input aperture 46 (or output aperture 48 see FIG. 4), but this shape can be hexagonal as shown in FIG. 5A, oval shaped, or another shape determined by materials, bonding, fluid pressures or combinations thereof.

**[0057]** A fifth film 62E can be located over the fourth film 62D. The fifth film 62E can be bonded to the fourth film 62D by a fourth bond 66D having the second bonding pattern 9. The fourth bond 66D having the second bonding pattern 9 does not include any bonding between the fourth film 62D and the fifth film 62E in the region of the Fluid A input aperture 46 of the fourth and fifth films 62D, 62E. A fourth channel 70D can be formed between the fourth film 62D and the fifth film 62E. The fourth channel 70D can be fluidly connected to the Fluid A flow passage 22. The fourth bond 66D bonds the Fluid B output aperture 52 of the fourth film 62D to the Fluid B output aperture 52 of the fifth film 62E so Fluid A and Fluid B cannot mix at the Fluid B output aperture 52.

**[0058]** The alternating of the first bonding pattern 10 and the second bonding pattern 9 can also create a fifth channel 70E which can be fluidly connected to the Fluid B flow passage 24. Fluid connections 30 are shown bonded to the outer surface 102 of a sixth film 62F. The fluid connections 30 can extend through the second reinforcement plate 18. The fluid connections 30 can form fluid connections using any device common to the industry. These connections can include welded flanges or mechanical bulkhead fittings.

**[0059]** FIG. 7 illustrates bonds in a schematic drawing of cross section 5B-5B of FIG. 4 (but having fewer film layers than FIG. 5B), in accordance with at least one example of the present subject matter. The film stack 1 can be sandwiched between the first reinforcement plate 16 and the second reinforcement plate 18. The five channels can be formed by alternating of the first bonding pattern 10 and the second bonding pattern 9. The Fluid B flow passage 24 can be fluidly coupled to the first channel 70A, the third channel 70C, and the fifth channel 70E. The Fluid A flow passage 22 can be fluidly coupled to the second channel 70B and the fourth channel 70D.

**[0060]** FIG. 8 illustrates bonds in a schematic drawing of cross section 5C-5C of FIG. 4 (but having fewer film layers than FIG. 5C), in accordance with at least one example of the present subject matter. Cross section 5C-5C can include the Fluid B input port 7 and the Fluid A output port 6. The film layers 20 are bonded in the same manner as in FIG. 6 with alternating bonding patterns that form the first channel 70A, the third channel 70C, and the fifth channel 70E fluidly coupled to the Fluid B flow passage 24. The Fluid A flow passage 22 is fluidly coupled to the second channel 70B and the fourth channel 70D.

**[0061]** Although the film stacks 1 in FIGS. 5A-C and FIGS. 6-8 are illustrated as having the first, third, fifth, etc. channels coupled to the Fluid B flow passage 24, in an example the first film and second film can be bonded with the second bonding pattern 9 instead of the first bonding pattern 10. If the patterns are alternated as described above, the Fluid B flow passage would then be coupled with the even numbered channels and the Fluid A flow passage would be coupled to the odd numbered channels (e.g. first channel, third channel, fifth channel etc.).

**[0062]** FIG. 9 illustrates a flow chart describing a method, in accordance with at least one example of the present heat exchanger. Method 900 includes at 910, bonding a first film and a second film. The first film and second film can be bonded by a first bond. The second film can be located over the first film in stacked alignment. The stacking can be substantially normal to a plane of the films. The first bond can include a first bond pattern. The first bond pattern can include bonding around a perimeter of the films and also bonding around one pair of fluid apertures. One pair of fluid apertures, an input port and an output port are not bonded and the first film and second film can have a first channel between them.

**[0063]** Method 900 includes at 920, bonding a second film and a third film. The third film can be located over the second film in stacked alignment. The second film and the third film can be bonded by a second bond. The second bond can include a second bonding pattern. The second bonding pattern can bond a perimeter between the second and third films. The second bond can form bonds around the respective pair of port apertures that are not bonded in the first bond and leave unbonded the respective pair of apertures that were bonded in the first bond. Such bonding can form a second channel between the second and third films. The second channel can be fluidly independent of the first channel. Although method 900 describes the first bond as having the first pattern, in another example, the first bond can have the second pattern. The first and second patterns are alternated, so if the first bond is the second pattern, the second bond will be the first pattern and so on.

**[0064]** Method 900 includes at 930, forming a first pair of ports. The first pair of ports can be in fluid communication with the first channel. Method 900 includes at 940 forming a second pair of ports. The second pair of ports can be in fluid communication with the second channel.

**[0065]** Method 900 can also include at 950, bonding a third film and a fourth film. The fourth film can be located over the third film in stacked alignment. The third film and the fourth film can be bonded by a third bond, having the first bonding pattern. The region bound by the third and fourth films can be fluidly coupled to the first channel. Method 900 can also include at 960, bonding a fourth film and a fifth film. The fifth film can be located over the fourth film in stacked alignment. The fourth film and the fifth film can be bonded by a fourth bond, having the second bonding pattern. The region bound by the fourth and fifth films can be fluidly coupled to the second channel.

**[0066]** Method 900 can also include at 970, forming both pairs of ports on a common side of the films. In an example, one pair of ports can be formed on one side of the films, while another pair of ports can be formed on the opposite side of the films. In an example, an input port for Fluid A and an input port for Fluid B can be formed on one side of the films, while an output port for Fluid A and an output port for Fluid B can be formed on the opposite side of the films. In an example, one port can be formed on one side of the films and three ports can be formed on the opposite side of the films. The additive sequence of 950 and 960 can be repeated for additional film layers to form the desired number of parallel flow channels.

**[0067]** Method 900 can also include at 975, films having a rectangular profile and having a pair of ports aligned on a common diagonal. The first film, the second film and the third film can have a substantially rectangular profile. Forming the first pair of ports can include forming a first input port and a first output port. The first input port and the first output port can be aligned on a common diagonal of the substantially rectangular profile. This diagonal port configuration encourages the counterflow interaction of Fluids A and B in during counterflow heat exchange.

**[0068]** Method 900 can also include at 980, bonding that includes at least one of a thermal joint, a weld joint or an adhesive joint. The bonding forms a fluid tight seal that separates fluids from intermixing and prevents leakages.

**[0069]** Method 900 can also include at 985, affixing a first reinforcement plate to a film. The reinforcement plate can be a rigid material made of polymer, rubber, plastic, metal, or combinations thereof Method 900 can also include at 990, affixing a second reinforcement plate to a film. The first and second reinforcement plates can sandwich the film layers between them. The reinforcement plates can prevent the layers of films from over-expanding from pressurized fluids, provide structural protection for the films, and provide a rigid structure for attachment to another structure. Method 900 can also include at 995, providing at least one spacer coupled to the reinforcement plates that can retain the plates in fixed alignment and at a predetermined distance apart. The spacer length can be adjusted to change the number of film layers or the expandable dimensions of channels between films.

**[0070]** The films used in method 900 are flexible. Additional bonds not needed for fluid channel sealing can be included patterns between adjacent film layers to encourage uniform expansion of film layers into a three dimensional form.

**[0071]** The above detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show, by way of illustration, specific embodiments of the heat exchanger. These embodiments are also referred to herein as "examples." Such examples can include elements in addition to those shown or described.

**[0072]** The description herein is intended to be illustrative, and not restrictive. For example, the above-described examples (or one or more aspects thereof) may be used in combination with each other. Other embodiments can be used, such as by one of ordinary skill in the art upon reviewing the above description. Thus, the following claims are hereby incorporated into the Detailed Description as examples or embodiments, with each claim standing on its own as a separate embodiment, and it is contemplated that such embodiments can be combined with each other in various combinations or permutations. The scope of the invention should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

## Claims

**1.** A device (15) comprising:

a plurality of polymer films (20) including a first film (62A) adjacent a second film (62B) and including a third film adjacent the second film (62B), the plurality of polymer films in a film stack (1) aligned on a stack axis normal to a plane of the plurality of polymer films, wherein the first film (62A) is bonded to the second film (62B) with a first bond (66A) having a first pattern (10) configured to form a first channel (70A) between the first film and the second film, and further wherein the second film (62B) is bonded to the third film (62C) with a second bond (66B) having a second pattern (9) configured to form a second channel (70B) between the second film and the third film;

a first pair of manifolds in the film stack (1), the first pair of manifolds formed by the plurality of polymer films (20) and fluidly coupled to the first channel (70A);

a second pair of manifolds in the film stack (1), the second pair of manifolds formed by the plurality of polymer films (20) and fluidly coupled to the second channel (70B);

a first pair of ports (5, 6) fluidly coupled to the first pair of manifolds, and a second pair of ports (7, 8) fluidly coupled to the second pair of manifolds, wherein the first pair of ports and the second pair of ports have port axes aligned substantially parallel with the stack axis; and

**characterized in that** the polymer films (20) are flexible and formed of a flattened sheet-like material such that the film stack (1), including the first channel (70A), the second channel (70B), the first pair of manifolds, and the second pair of manifolds, is configured to expand along the stack axis when pressurized with a fluid.

**2.** The device of claim 1 wherein the third film (62C) is bonded to a fourth film (66D) with a third bond (66C), the third bond having the first pattern (10) and wherein the first channel (70A) and the first pair of manifolds are fluidly coupled to a region bound by the third film and the fourth film; and
wherein preferably the fourth film (62D) is bonded to a fifth film (62E) with a fourth bond (66D), the fourth bond having the second pattern (9) and wherein the second channel (70B) and the second pair of manifolds are fluidly coupled to a region bound by the fourth film and the fifth film.

**3.** The device of any one of claims 1-2 wherein the first channel (70A) is bound by the first bond (66A) and wherein the second channel (70B) is bound by the second bond (66B).

**4.** The device of any one of claims 1-2 wherein the first pair of ports and the second pair of ports are on a common side of the plurality of flexible polymer films (20).

**5.** The device of any one of claims 1-2 wherein each of the flexible polymer films of the plurality of flexible polymer films have a substantially rectangular profile (34) and wherein the first pair of ports includes a first input port (5) and includes a first output port (6) and wherein the first input port and the first output port are aligned on a common diagonal (38) determined by the substantially rectangular profile (34).

**6.** The device of any one of claims 1-2 wherein the first channel (70A) is fluidly isolated from the second channel (70B).

**7.** The device of any one of claims 1-2 further including a first reinforcement plate (16) coupled to a first selected polymer film of the plurality of flexible polymer films (20).

**8.** The device of claim 7 further including a second reinforcement plate (18) coupled to a second selected polymer film of the plurality of flexible polymer films (20).

**9.** The device of claim 8 further including at least one spacer (4) coupled to the first reinforcement plate (16) and coupled to the second reinforcement plate (18), wherein the at least one spacer is configured to retain the first reinforcement plate and the second reinforcement plate in fixed alignment and at a predetermined distance (44) apart, and wherein expansion of the film stack (1) is limited by the predetermined distance.

**10.** A method to manufacture a device as defined in claim 1 comprising:

forming a first bond (66A) coupling a first polymer film (62A) and a second polymer film (62B), the first bond having a first bond pattern (10), the first polymer film and the second polymer film in stacked alignment and having a first channel (70A) therebetween;
forming a second bond (66B) coupling the second polymer film (62B) and a third polymer film (62C), the second bond having a second bond pattern (9), the second polymer film and the third polymer film in stacked alignment and having a second channel (70B) therebetween, the second channel (70B) fluidly independent of the first channel (70A), and wherein a plurality of bonded polymer films (20) forms a film stack (1) having a stack axis normal to a plane of the plurality of bonded polymer films;
forming a first pair of manifolds with the plurality of polymer films, wherein the first pair of manifolds are fluidly coupled to the first channel (70A);
forming a second pair of manifolds with the plurality of polymer films, wherein the second pair of manifolds are fluidly coupled to the second channel (70B);
forming a first pair of ports (5, 6) in the first film (62A), the first pair of ports in fluid communication with the first pair of manifolds; and
forming a second pair of ports (7, 8) in the third film (62C), the second pair of ports in fluid communication with the second pair of manifolds; and

**characterized in that** the polymer films (20) are flexible and formed of a flattened sheet-like material such that the film stack (1), including the first channel (70A), the second channel (70B), the first pair of manifolds, and the second pair of manifolds, is configured to expand along the stack axis when pressurized with a fluid.

**11.** The method of claim 10 further including forming a third bond (66C) coupling the third flexible polymer film (62C) and a fourth flexible polymer film (62D), the third bond having the first bond pattern (10), the third flexible polymer film and the fourth flexible polymer film in stacked alignment and wherein the first channel (70A) and the first pair of manifolds are fluidly coupled to a region bound by the third flexible polymer film and the fourth flexible polymer film.

**12.** The method of claim 11 further including forming a fourth bond (66D) coupling the fourth flexible polymer film (62D) and a fifth flexible polymer film (62E), the fourth bond having the second bond pattern (9), the fourth flexible polymer film and the fifth flexible polymer film in stacked alignment and wherein the second channel (70B) and the second pair of manifolds are fluidly coupled to a region bound by the fourth flexible polymer film and the fifth flexible polymer film.

**13.** The method of any one of claims 10-12 wherein forming the first pair of ports (5, 6) and forming the second pair of ports (7, 8) includes forming on a common side of the films.

**14.** The method of any one of claims 10-12 wherein the first flexible polymer film (62A), the second flexible polymer film (62B), and the third flexible polymer film (62C) have a substantially rectangular profile (34) and wherein forming the first pair of ports includes forming a first input port (5) and includes forming a first output port (6) and wherein the first input port and the first output port are aligned on a common diagonal (38) determined by the substantially rectangular profile (34).

**15.** The method of any one of claims 10-12 further including affixing a first reinforcement plate (16) to the first flexible polymer film (62A); and
preferably further including affixing a second reinforcement plate (18) coupled to a flexible polymer film; and
further preferably further including providing at least one spacer (4) coupled to the first reinforcement plate (16) and coupled to the second reinforcement plate (18), wherein the at least one spacer is configured to retain the first reinforcement plate and the second reinforcement plate in fixed alignment and

at a predetermined distance apart (44).

## Patentansprüche

1. Vorrichtung (15), die Folgendes umfasst:

eine Mehrzahl von Polymerfolien (20), die eine erste Folie (62A) neben einer zweiten Folie (62B) und eine dritte Folie neben der zweiten Folie (62B) beinhaltet, wobei die Mehrzahl von Polymerfolien in einem Folienstapel (1) auf einer Stapelachse lotrecht zu einer Ebene der Mehrzahl von Polymerfolien ausgerichtet ist, wobei die erste Folie (62A) an die zweite Folie (62B) mit einer ersten Bindung (66A), die ein erstes Muster (10) aufweist, gebunden ist, das so konfiguriert ist, dass ein erster Kanal (70A) zwischen der ersten Folie und der zweiten Folie gebildet wird, wobei die zweite Folie (62B) ferner an die dritte Folie (62C) mit einer zweiten Bindung (66B), die ein zweites Muster (9) aufweist, gebunden ist, das so konfiguriert ist, dass ein zweiter Kanal (70B) zwischen der zweiten Folie und der dritten Folie gebildet wird;
ein erstes Paar Verteiler in dem Folienstapel (1), wobei das erste Paar Verteiler durch die Mehrzahl von Polymerfolien (20) gebildet und mit dem ersten Kanal (70A) fluidisch gekoppelt ist;
ein zweites Paar Verteiler in dem Folienstapel (1), wobei das zweite Paar Verteiler durch die Mehrzahl von Polymerfolien (20) gebildet und mit dem zweiten Kanal (70B) fluidisch gekoppelt ist;
ein erstes Paar Öffnungen (5, 6), die mit dem ersten Paar Verteiler fluidisch gekoppelt sind, und ein zweites Paar Öffnungen (7, 8), die mit dem zweiten Paar Verteiler fluidisch gekoppelt sind, wobei das erste Paar Öffnungen und das zweite Paar Öffnungen Öffnungsachsen haben, die im Wesentlichen parallel zur Stapelachse ausgerichtet sind; und

**dadurch gekennzeichnet, dass** die Polymerfolien (20) flexibel und aus einem abgeflachten plattenförmigen Material gebildet sind, so dass der Folienstapel (1), der den ersten Kanal (70A), den zweiten Kanal (70B), das erste Verteilerpaar und das zweite Verteilerpaar beinhaltet, so konfiguriert ist, dass er entlang der Stapelachse expandiert, wenn er mit einem Fluid unter Druck gesetzt wird.

2. Vorrichtung nach Anspruch 1, wobei die dritte Folie (62C) an eine vierte Folie (66D) mit einer dritten Bindung (66C) gebunden ist, wobei die dritte Bindung das erste Muster (10) hat und wobei der erste Kanal (70A) und das erste Verteilerpaar mit einer durch die dritte Folie und die vierte Folie begrenzten Region fluidisch gekoppelt sind; und
wobei die vierte Folie (62D) vorzugsweise an eine fünfte Folie (62E) mit einer vierten Bindung (66D) gebunden ist, wobei die vierte Bindung das zweite Muster (9) hat, und wobei der zweite Kanal (70B) und das zweite Verteilerpaar mit einer durch die vierte Folie und die fünfte Folie begrenzten Region fluidisch gekoppelt sind.

3. Vorrichtung nach einem der Ansprüche 1-2, wobei der erste Kanal (70A) durch die erste Bindung (66A) gebunden ist und der zweite Kanal (70B) durch die zweite Bindung (66B) gebunden ist.

4. Vorrichtung nach einem der Ansprüche 1-2, wobei das erste Paar Öffnungen und das zweite Paar Öffnungen auf einer gemeinsamen Seite der Mehrzahl von flexiblen Polymerfolien (20) angeordnet sind.

5. Vorrichtung nach einem der Ansprüche 1-2, wobei jede der flexiblen Polymerfolien der Mehrzahl von flexiblen Polymerfolien ein im Wesentlichen rechteckiges Profil (34) hat und wobei das erste Paar Öffnungen eine erste Eingangsöffnung (5) und eine erste Ausgangsöffnung (6) beinhaltet und wobei die erste Eingangsöffnung und die erste Ausgangsöffnung auf einer gemeinsamen Diagonale (38) ausgerichtet sind, die durch das im Wesentlichen rechteckige Profil (34) festgelegt ist.

6. Vorrichtung nach einem der Ansprüche 1-2, wobei der erste Kanal (70A) vom zweiten Kanal (70B) fluidisch isoliert ist.

7. Vorrichtung nach einem der Ansprüche 1-2, die ferner eine erste Verstärkungsplatte (16) beinhaltet, die mit einer ersten ausgewählten Polymerfolie der Mehrzahl von flexiblen Polymerfolien (20) gekoppelt ist.

8. Vorrichtung nach Anspruch 7, die ferner eine zweite Verstärkungsplatte (18) beinhaltet, die mit einer zweiten ausgewählten Polymerfolie der Mehrzahl von flexiblen Polymerfolien (20) gekoppelt ist.

9. Vorrichtung nach Anspruch 8, die ferner wenigstens einen Abstandshalter (4) beinhaltet, der mit der ersten Verstärkungsplatte (16) und der zweiten Verstärkungsplatte (18) gekoppelt ist, wobei der wenigstens eine Abstandshalter zum Halten der ersten Verstärkungsplatte und der zweiten Verstärkungsplatte in fester Ausrichtung und in einem vorbestimmten Abstand (44) voneinander konfiguriert ist und wobei die Expansion des Folienstapels (1) durch den vorbestimmten Abstand beschränkt ist.

10. Verfahren zur Herstellung einer Vorrichtung gemäß Definition in Anspruch 1, das Folgendes beinhaltet:

Bilden einer ersten Bindung (66A), die eine erste Polymerfolie (62A) und eine zweite Polymerfolie (62B) koppelt, wobei die erste Bindung ein erstes Bindungsmuster (10) hat, wobei die erste Polymerfolie und die zweite Polymerfolie in gestapelter Ausrichtung und mit einem ersten Kanal (70A) dazwischen sind;

Bilden einer zweiten Bindung (66B), die die zweite Polymerfolie (62B) und eine dritte Polymerfolie (62C) koppelt, wobei die zweite Bindung ein zweites Bindungsmuster (9) hat, wobei die zweite Polymerfolie und die dritte Polymerfolie in gestapelter Ausrichtung mit einem zweiten Kanal (70B) dazwischen sind, wobei der zweite Kanal (70B) vom ersten Kanal (70A) fluidisch unabhängig ist und wobei eine Mehrzahl von gebundenen Polymerfolien (20) einen Folienstapel (1) mit einer Stapelachse lotrecht zu einer Ebene der Mehrzahl von gebundenen Polymerfolien bildet;

Bilden eines ersten Paares von Verteilern mit der Mehrzahl von Polymerfolien, wobei das erste Paar Verteiler mit dem ersten Kanal (70A) fluidisch gekoppelt ist;

Bilden eines zweiten Paares von Verteilern mit der Mehrzahl von Polymerfolien, wobei das zweite Paar Verteiler mit dem zweiten Kanal (70B) fluidisch gekoppelt ist;

Bilden eines ersten Paares von Öffnungen (5, 6) in der ersten Folie (62A), wobei das erste paar Öffnungen in Fluidkommunikation mit dem ersten Paar Verteiler ist; und

Bilden eines zweiten Paares von Öffnungen (7, 8) in der dritten Folie (62C), wobei das zweite Paar Öffnungen in Fluidkommunikation mit dem zweiten Paar Verteiler ist; und

**dadurch gekennzeichnet, dass** die Polymerfolien (20) flexibel sind und aus einem abgeflachten plattenförmigen Material gebildet sind, so dass der Folienstapel (1), der den ersten Kanal (70A), den zweiten Kanal (70B), das erste Verteilerpaar und das zweite Verteilerpaar beinhaltet, so konfiguriert ist, dass er entlang der Stapelachse expandiert, wenn er mit einem Fluid unter Druck gesetzt wird.

**11.** Verfahren nach Anspruch 10, das ferner das Bilden einer dritten Bindung (66C) beinhaltet, die die dritte flexible Polymerfolie (62C) und eine vierte flexible Polymerfolie (62D) koppelt, wobei die dritte Bindung das erste Bindungsmuster (10) hat, die dritte flexible Polymerfolie und die vierte flexible Polymerfolie in gestapelter Ausrichtung sind und wobei der erste Kanal (70A) und das erste Verteilerpaar mit einer durch die dritte flexible Polymerfolie und die vierte flexible Polymerfolie begrenzte Region fluidisch gekoppelt sind.

**12.** Verfahren nach Anspruch 11, das ferner das Bilden einer vierten Bindung (66D) beinhaltet, die die vierte flexible Polymerfolie (62D) und eine fünfte flexible Polymerfolie (62E) koppelt, wobei die vierte Bindung das zweite Bindungsmuster (9) hat, die vierte flexible Polymerfolie und die fünfte flexible Polymerfolie in gestapelter Ausrichtung sind und wobei der zweite Kanal (70B) und das zweite Verteilerpaar mit einer durch die vierte flexible Polymerfolie und die fünfte flexible Polymerfolie begrenzte Region fluidisch gekoppelt sind.

**13.** Verfahren nach einem der Ansprüche 10-12, wobei das Bilden des ersten Paares von Öffnungen (5, 6) und das Bilden des zweiten Paares von Öffnungen (7, 8) das Bilden auf einer gemeinsamen Seite der Folien beinhaltet.

**14.** Verfahren nach einem der Ansprüche 10-12, wobei die erste flexible Polymerfolie (62A), die zweite flexible Polymerfolie (62B) und die dritte flexible Polymerfolie (62C) ein im Wesentlichen rechteckiges Profil (34) haben und wobei das Bilden des ersten Paares von Öffnungen das Bilden einer ersten Eingangsöffnung (5) beinhaltet und das Bilden einer ersten Ausgangsöffnung (6) beinhaltet und wobei die erste Eingangsöffnung und die erste Ausgangsöffnung auf einer gemeinsamen Diagonale (38) ausgerichtet sind, die durch das im Wesentlichen rechteckige Profil (34) festgelegt ist.

**15.** Verfahren nach einem der Ansprüche 10-12, das ferner das Befestigen einer ersten Verstärkungsplatte (16) an der ersten flexiblen Polymerfolie (62A) beinhaltet; und

vorzugsweise ferner das Befestigen einer zweiten Verstärkungsplatte (18) beinhaltet, die mit einer flexiblen Polymerfolie gekoppelt wird; und

ferner vorzugsweise das Bereitstellen von wenigstens einem Abstandshalter (4) beinhaltet, der mit der ersten Verstärkungsplatte (16) und der zweiten Verstärkungsplatte (18) gekoppelt wird, wobei der wenigstens eine Abstandshalter zum Halten der ersten Verstärkungsplatte und der zweiten Verstärkungsplatte in fester Ausrichtung und in einem vorbestimmten Abstand (44) voneinander konfiguriert ist.

## Revendications

**1.** Un dispositif (15) comprenant :

une pluralité de films polymères (20) comprenant un premier film (62A) adjacent à un deuxième film (62B) et comprenant un troisième film adjacent au deuxième film (62B), la pluralité de films polymères dans une pile de films (1) étant alignés sur un axe d'empilement perpendiculai-

re à un plan de la pluralité des films polymères, le premier film (62A) étant lié au deuxième film (62B) par une première liaison (66A) présentant un premier motif (10) configuré pour former un premier canal (70A) entre le premier film et le deuxième film, et de plus le deuxième film (62B) étant lié au troisième film (62C) par une deuxième liaison (66B) présentant un deuxième motif (9) configuré pour former un deuxième canal (70B) entre le deuxième film et le troisième film ;
une première paire de collecteurs dans la pile de films (1), la première paire de collecteurs étant formée par la pluralité de films polymères (20) et couplée fluidiquement au premier canal (70A) ;
une deuxième pair de collecteurs dans la pile de films (1), la deuxième paire de collecteurs étant formée par la pluralité de films polymères (20) et couplée fluidiquement au deuxième canal (70B) ;
une première paire d'orifices (5, 6) couplée fluidiquement à la première paire de collecteurs, et une deuxième paire d'orifices (7, 8) couplée fluidiquement à la deuxième paire de collecteurs, la première paire d'orifices et la deuxième paire d'orifices possédant des axes d'orifices alignés sensiblement parallèlement à l'axe de la pile ; et **caractérisé en ce que** les films polymères (20) sont flexibles et formés par un matériau en feuille aplati de sorte que la pile de films (1), y compris le premier canal (70A), le deuxième canal (70B), la première paire de collecteurs et la deuxième paire de collecteurs, est configurée pour s'agrandir le long de l'axe de la pile quand elle est mise sous pression avec un fluide.

**2.** Le dispositif de la revendication 1 dans lequel le troisième film (62C) est lié à un quatrième film (66D) par une troisième liaison (66C), la troisième liaison présentant le premier motif (10) et le premier canal (70A) et la première paire de collecteurs étant couplés fluidiquement à une section entourée par le troisième film et le quatrième film ; et
dans lequel de préférence le quatrième film (62D) est lié à un cinquième film (62E) par une quatrième liaison (66D), la quatrième liaison présentant le deuxième motif (9) et dans lequel le deuxième canal (70B) et la deuxième paire de collecteurs sont couplés fluidiquement à une section entourée par le quatrième film et le cinquième film.

**3.** Le dispositif d'une quelconque des revendications 1-2 dans lequel le premier canal (70A) est entouré par la première liaison (66A) et dans lequel le deuxième canal (70B) est entouré par la deuxième liaison (66B).

**4.** Le dispositif d'une quelconque des revendications 1-2 dans lequel la première paire d'orifices et la deuxième paire d'orifices sont sur un côté commun de la pluralité des films polymères flexibles (20).

**5.** Le dispositif d'une quelconque des revendications 1-2 dans lequel chacun des films polymères flexibles de la pluralité des films polymères flexibles présente un profil sensiblement rectangulaire (34) et dans lequel la première paire d'orifices comprend un premier orifice d'entrée (5) et comprend un premier orifice de sortie (6) et dans lequel le premier orifice d'entrée et le premier orifice de sortie sont alignés sur une diagonale commune (38) déterminée par le profil sensiblement rectangulaire (34).

**6.** Le dispositif d'une quelconque des revendications 1-2 dans lequel le premier canal (70A) est isolé fluidiquement du deuxième canal (70B).

**7.** Le dispositif d'une quelconque des revendications 1-2 comprenant en sus une première plaque de renfort (16) couplée à un premier film polymère choisi parmi la pluralité des films polymères flexibles (20).

**8.** Le dispositif de la revendication 7 comprenant en sus une deuxième plaque de renfort (18) couplée à un deuxième film polymère choisi parmi la pluralité des films polymères flexibles (20).

**9.** Le dispositif de la revendication 8 comprenant en sus au moins un espaceur (4) couplé à la première plaque de renfort (16) et couplé à la deuxième plaque de renfort (18), le au moins un espaceur étant configuré pour retenir la première plaque de renfort et la deuxième plaque de renfort en alignement fixe et à une distance prédéterminée (44) l'une de l'autre, et dans lequel l'expansion de la pile de films (1) est limitée par la distance prédéterminée.

**10.** Un procédé de fabrication d'un dispositif selon la revendication 1, comprenant les étapes consistant à :

former une première liaison (66A) couplant un premier film polymère (62A) et un deuxième film polymère (62B), la première liaison présentant un premier motif de liaison (10), le premier film polymère et le deuxième film polymère étant en alignement empilé et présentant un premier canal (70A) entre eux ;
former une deuxième liaison (66B) couplant le deuxième film polymère (62B) et un troisième film polymère (62C), la deuxième liaison présentant un deuxième motif de liaison (9), le deuxième film polymère et le troisième film polymère étant en alignement empilé et présentant un deuxième canal (70B) entre eux, le deuxième canal (70B) étant fluidiquement indépendant du premier canal (70A), et dans lequel une pluralité

de films polymères liés (20) forme une pile de films (1) présentant un axe de pile perpendiculaire à un plan de la pluralité des films polymères liés ;

former une première paire de collecteurs avec la pluralité de films polymères, dans lequel la première paire de collecteurs est couplée fluidiquement au premier canal (70A) ;

former une deuxième paire de collecteurs avec la pluralité de films polymères, dans lequel la deuxième paire de collecteurs est couplée fluidiquement au deuxième canal (70B) ;

former une première paire d'orifices (5, 6) dans le premier film (62A), la première paire d'orifices étant en communication fluidique avec la première paire de collecteurs ; et

former une deuxième paire d'orifices (7, 8) dans le troisième film (62C), la deuxième paire d'orifices étant en communication fluidique avec la deuxième paire de collecteurs ; et

**caractérisé en ce que** les films polymères (20) sont flexibles et formés d'un matériau en forme de feuille aplati de sorte que la pile de films (1), y compris le premier canal (70A), le deuxième canal (70B), la première paire de collecteurs et la deuxième paire de collecteurs est configurée pour s'agrandir le long de l'axe de la pile quand elle est mise sous pression avec un fluide.

**11.** Le procédé de la revendication 10 comprenant en sus former une troisième liaison (66C) couplant le troisième film polymère flexible (62C) et un quatrième film polymère flexible (62D), la troisième liaison présentant le premier motif de liaison (10), le troisième film polymère flexible et le quatrième film polymère flexible étant en alignement empilé et dans lequel le premier canal (70A) et la première paire de collecteurs sont couplés fluidiquement à une section entourée par le troisième film polymère flexible et le quatrième film polymère flexible.

**12.** Le procédé de la revendication 11 comprenant en sus former une quatrième liaison (66D) couplant le film polymère flexible (62D) et un cinquième film polymère flexible (62E), la quatrième liaison présentant le deuxième motif de liaison (9), le quatrième film polymère flexible et le cinquième film polymère flexible étant en alignement empilé et dans lequel le deuxième canal (70B) et la deuxième paire de collecteurs sont couplés fluidiquement à une section entourée par le quatrième film polymère flexible et le cinquième film polymère flexible.

**13.** Le procédé d'une quelconque des revendications 10-12 dans lequel former la première paire d'orifices (5, 6) et former la deuxième paire d'orifices (7, 8) comprend former sur un côté commun des films.

**14.** Le procédé d'une quelconque des revendications 10-12 dans lequel le premier film polymère flexible (62A), le deuxième film polymère flexible (62B) et le troisième film polymère flexible (62C) ont un profil sensiblement rectangulaire (34) et dans lequel former la première paire d'orifices comprend former un premier orifice d'entrée (5) et comprend former un premier orifice de sortie (6) et dans lequel le premier orifice d'entrée et le premier orifice de sortie sont alignés sur une diagonale commune (38) déterminée par le profil sensiblement rectangulaire (34).

**15.** Le procédé d'une quelconque des revendications 10-12 comprenant en sus fixer une première plaque de renfort (16) au premier film polymère flexible (62A) ; et

de préférence comprenant en sus fixer une deuxième plaque de renfort (18) couplée à un film polymère flexible ; et

encore plus de préférence comprenant en sus prévoir au moins un espaceur (4) couplé à la première plaque de renfort (16) et couplé à la deuxième plaque de renfort (18), le au moins un espaceur étant configuré pour retenir la première plaque de renfort et la deuxième plaque de renfort en alignement fixe à une distance prédéterminée l'une de l'autre (44).

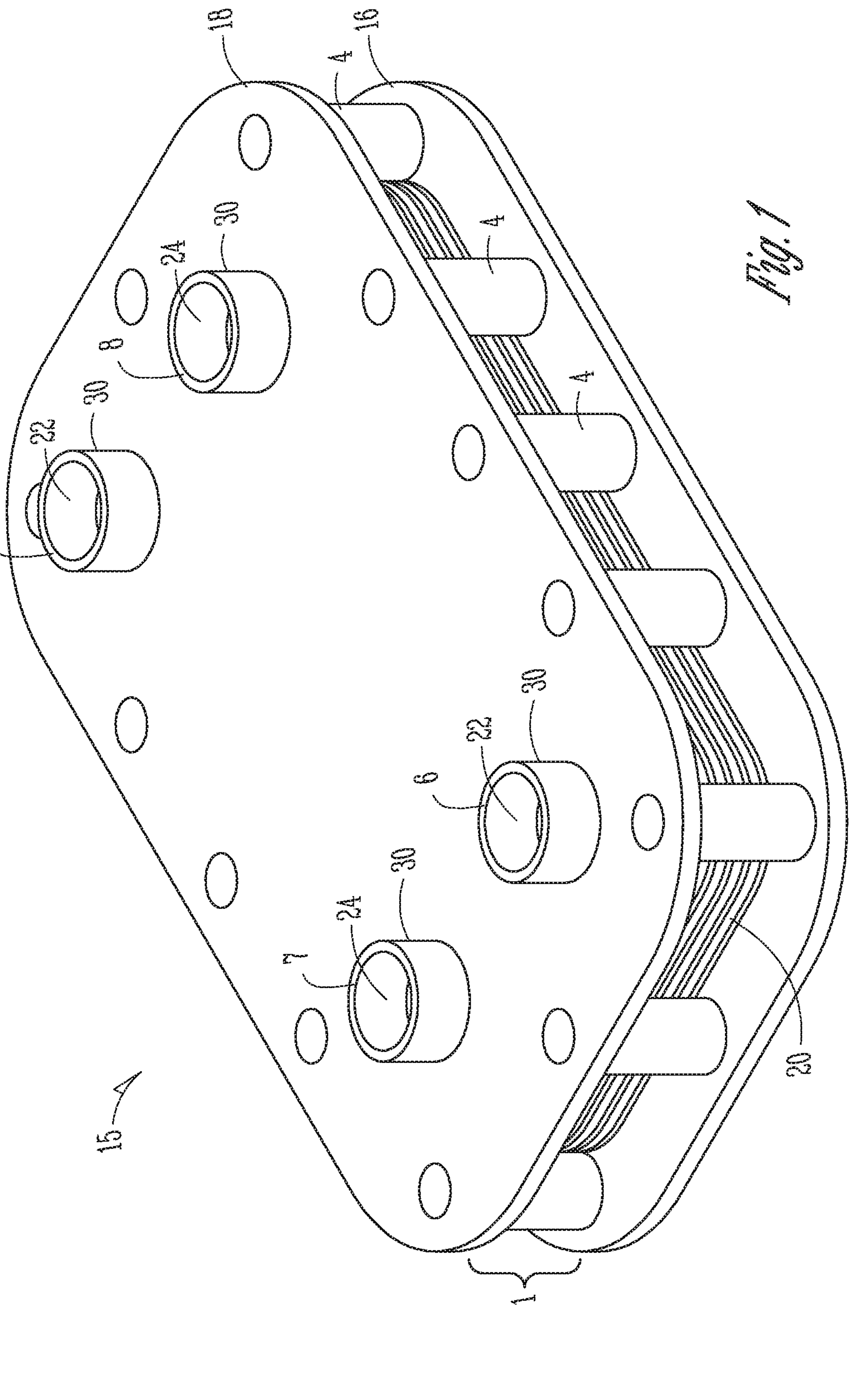


*Fig. 1*

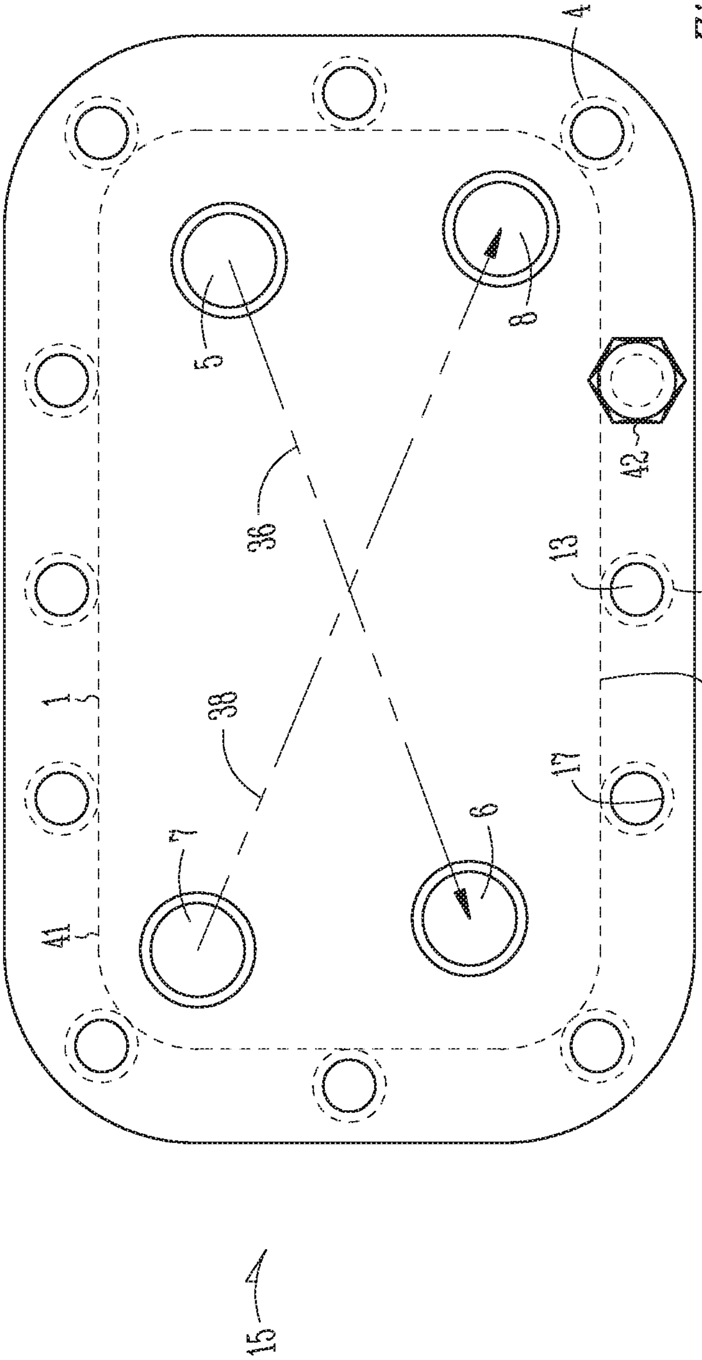


Fig.2

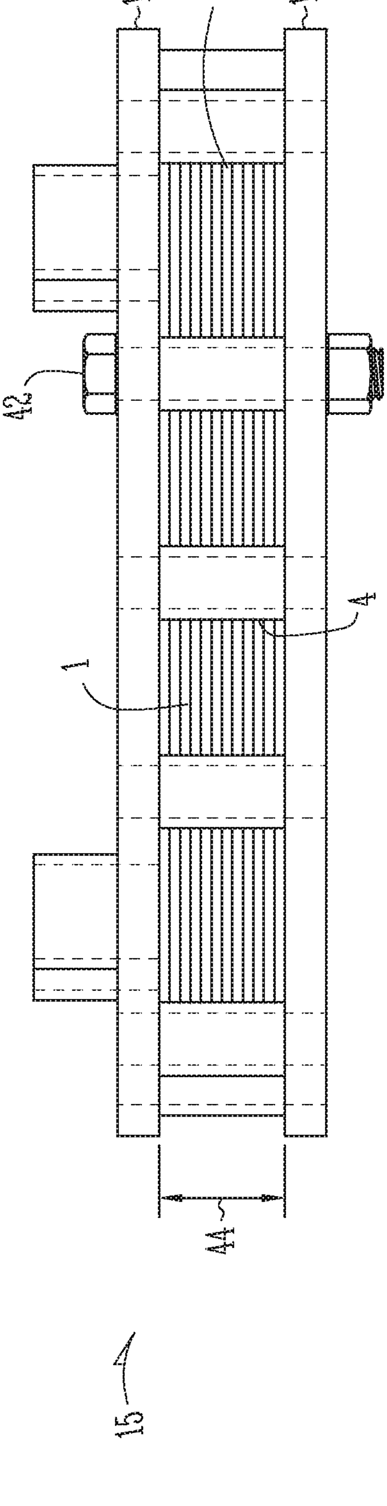


Fig.3

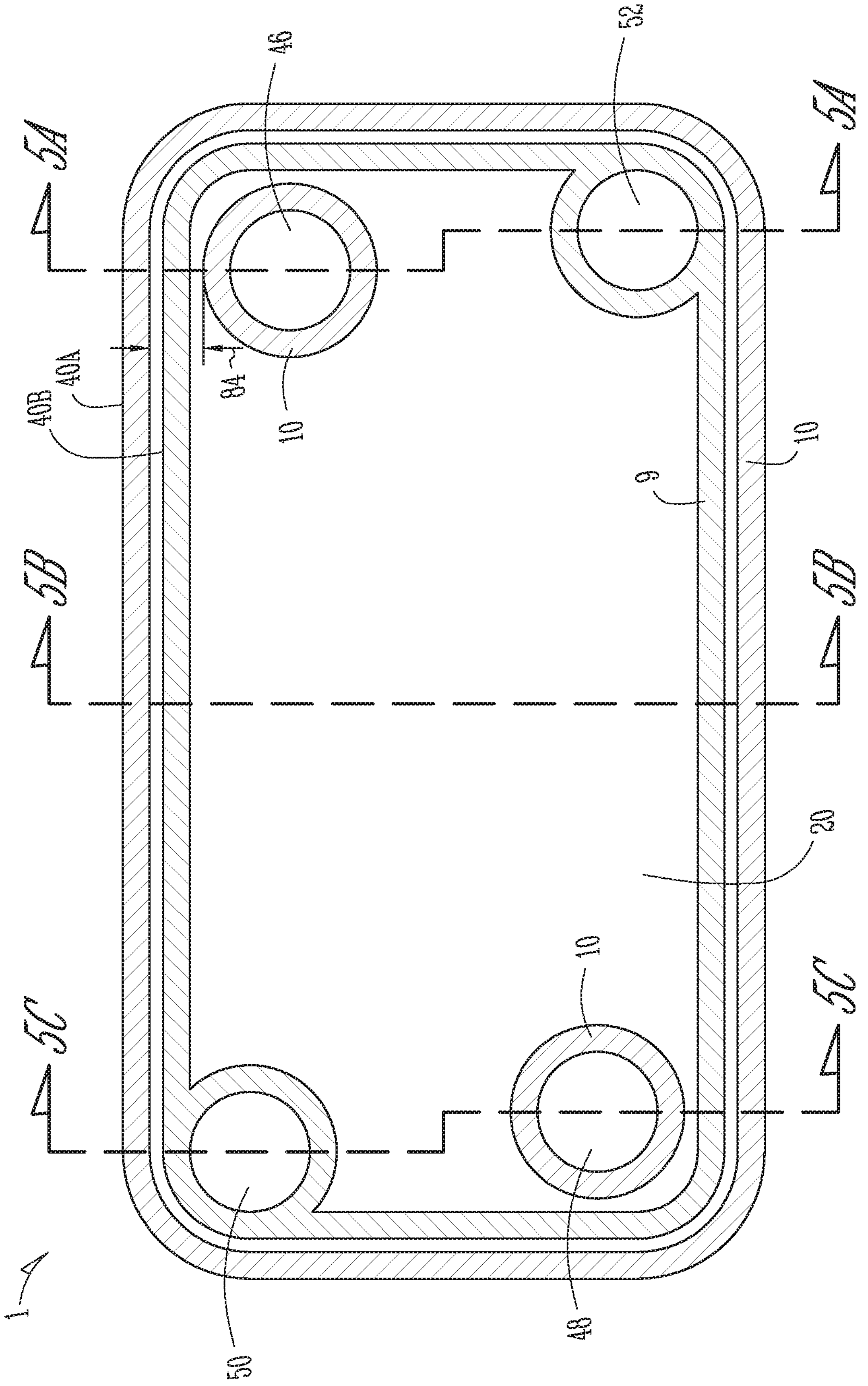


Fig. 4

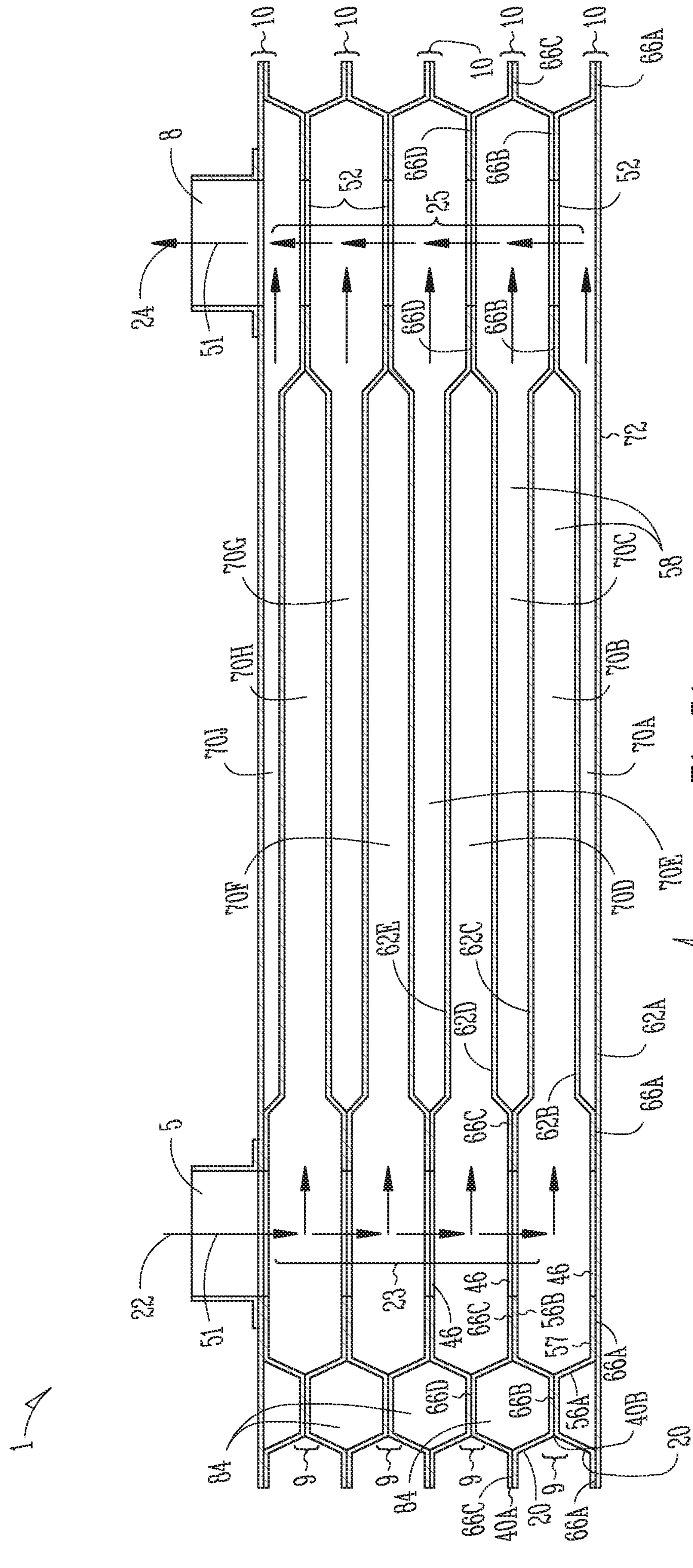
1
5
8
9
10
20
22
23
24
25
46
51
52
56A
56B
57
58
60
62A
62B
62C
62D
62E
66A
66B
66C
66D
70A
70B
70C
70D
70E
70F
70G
70H
70J
72
84
40A
40B

*Fig. 5A*

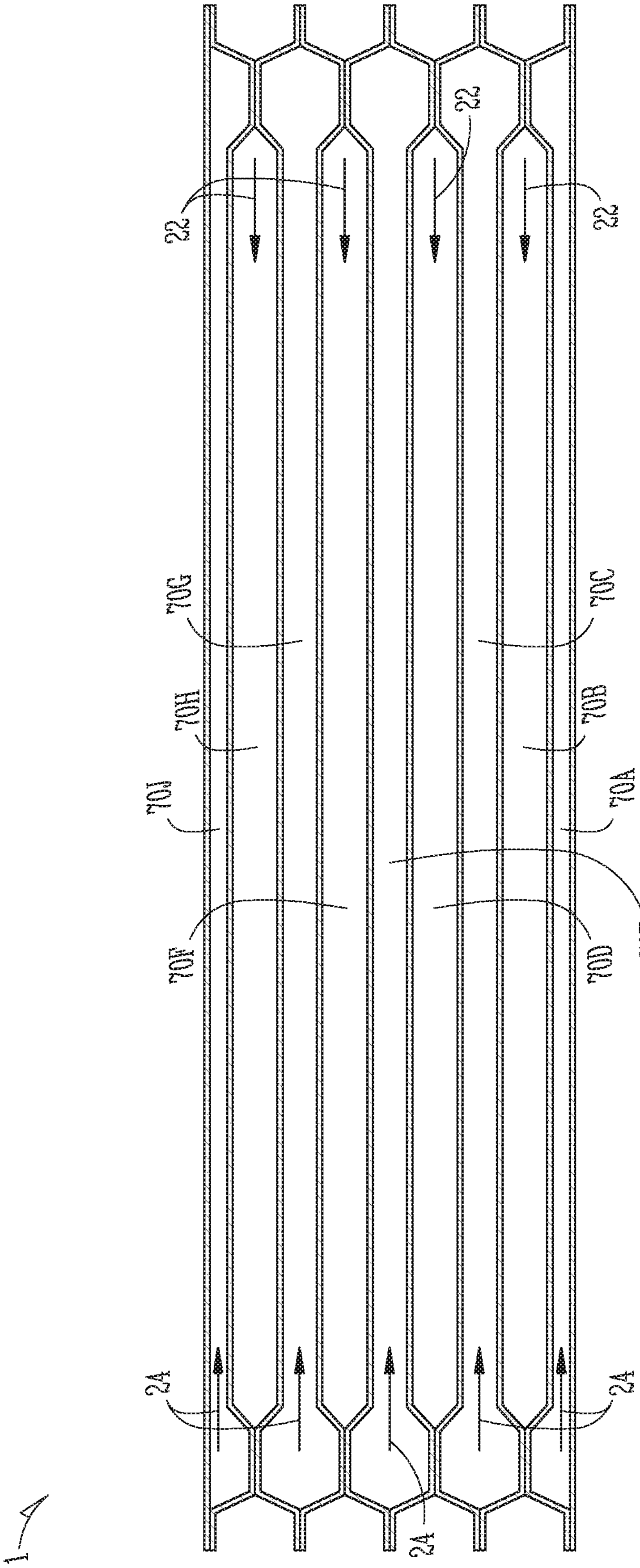


Fig.5B

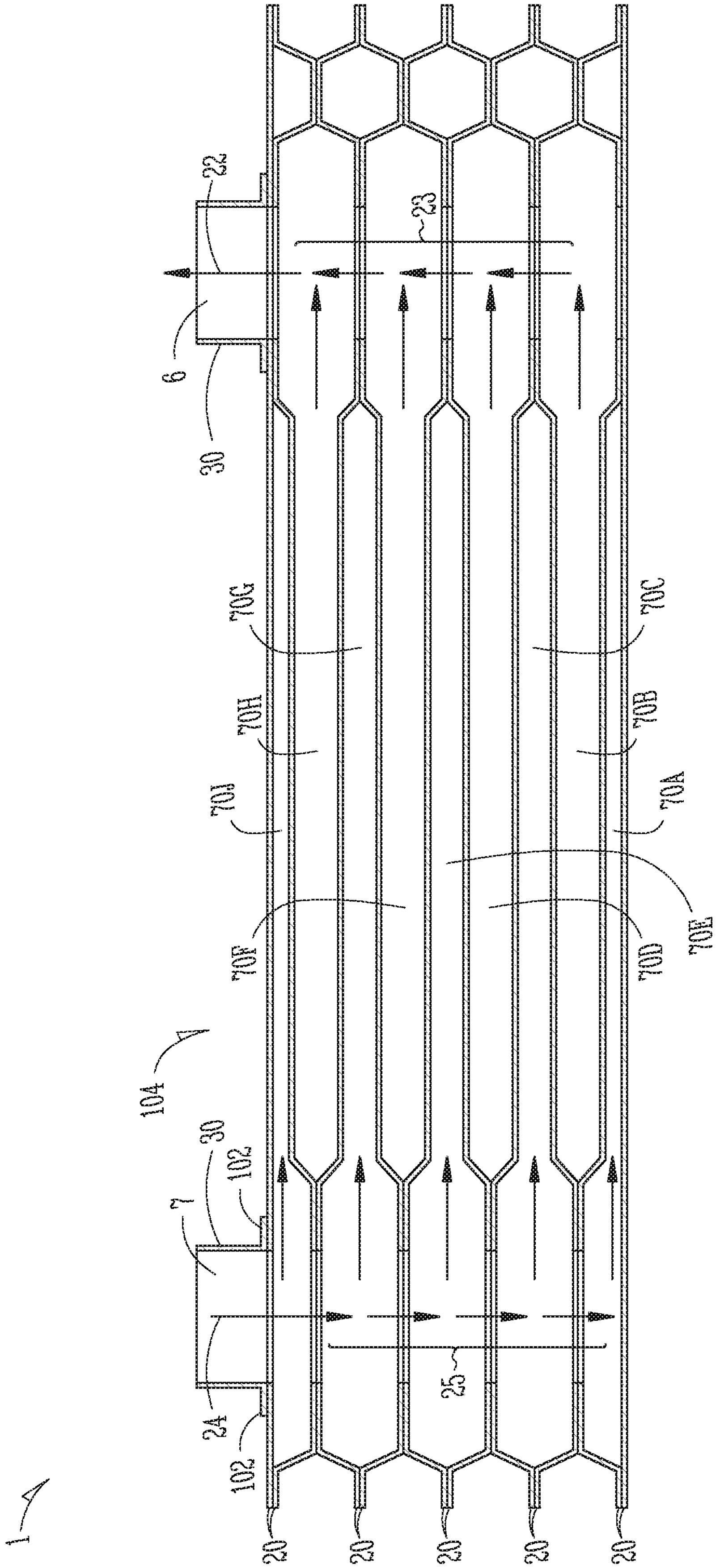
22
23
6
30
70G
70C
70H
70B
70J
70A
70F
70D
70E
104
30
102
7
24
102
25
1
20
20
20
20
20

*Fig.5C*

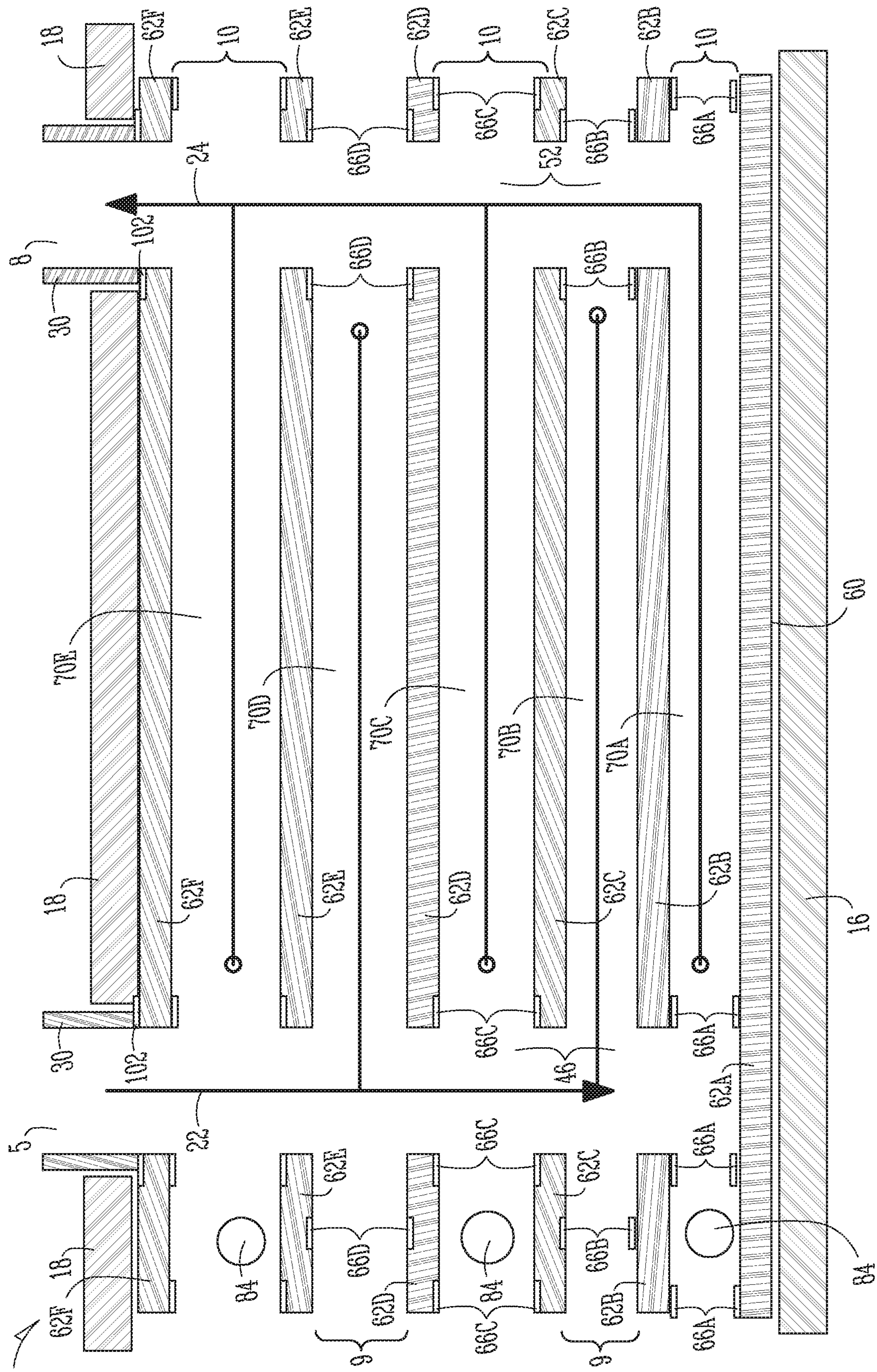
1
5
8
9
10
16
18
22
24
30
46
52
60
62A
62B
62C
62D
62E
62F
66A
66B
66C
66D
70A
70B
70C
70D
70E
84
102

*Fig. 6*

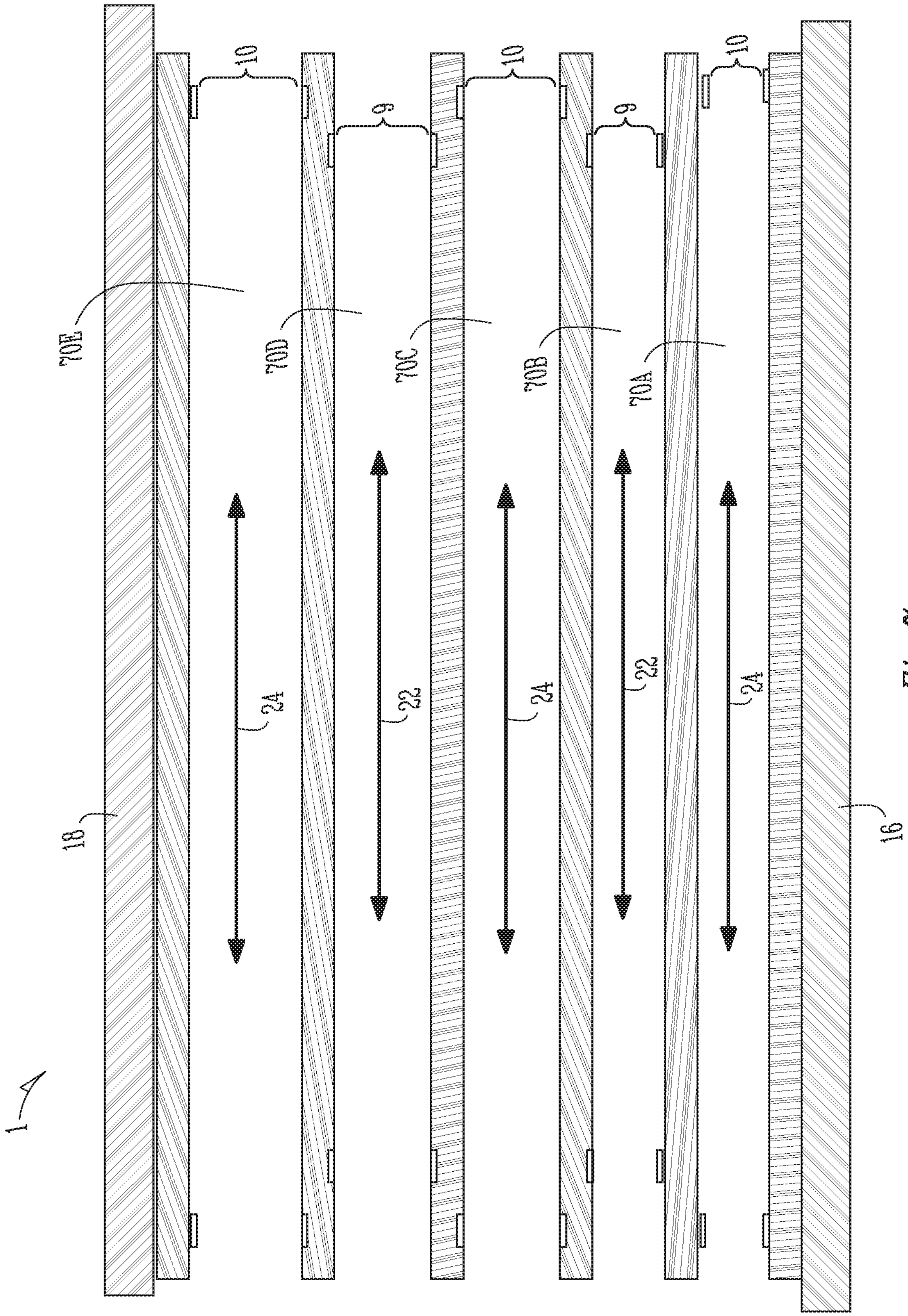


Fig. 7

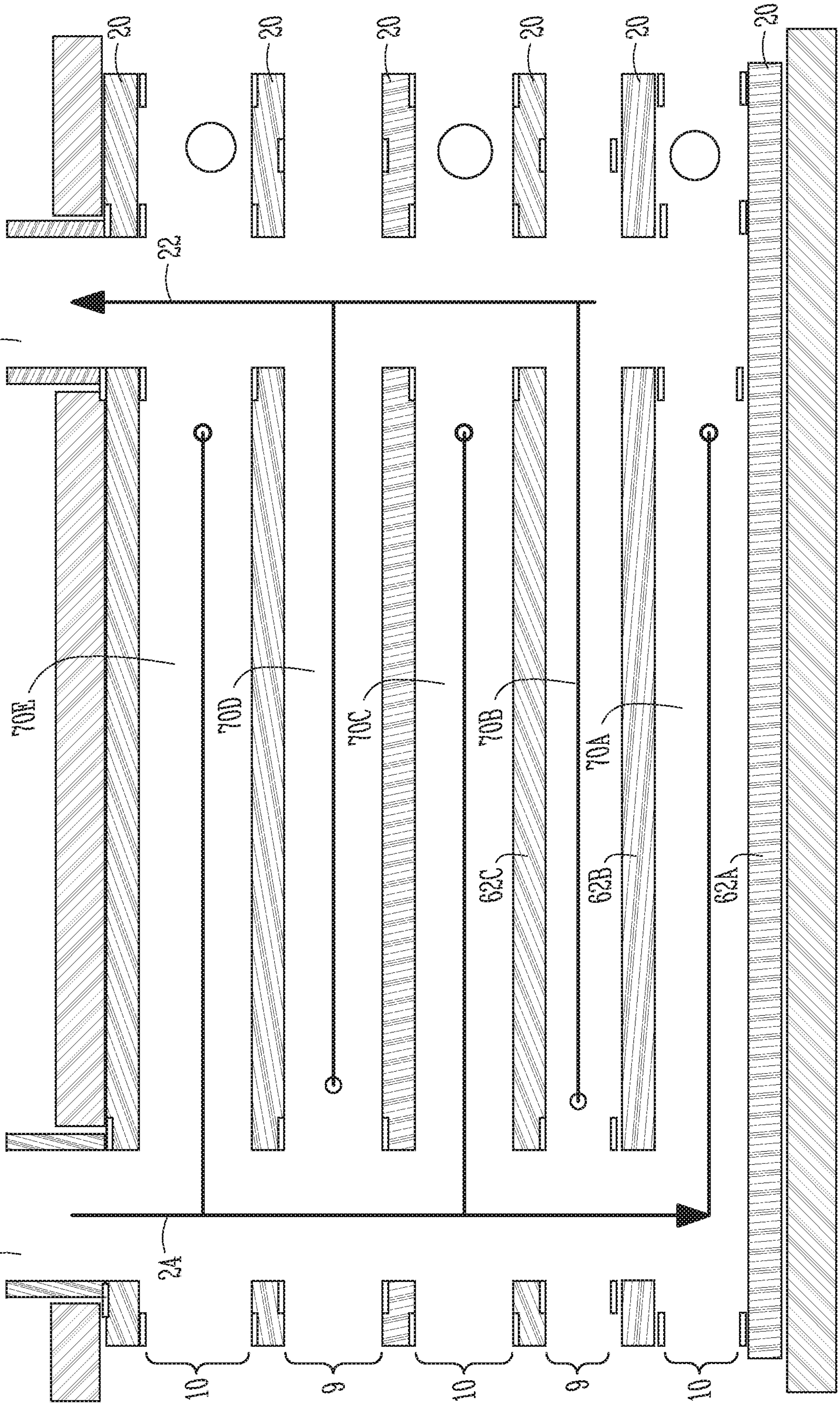
20
20
20
20
20
20
22
6
1
70E
70D
70C
70B
70A
62C
62B
62A
7
24
10
9
10
9
10

Fig.8

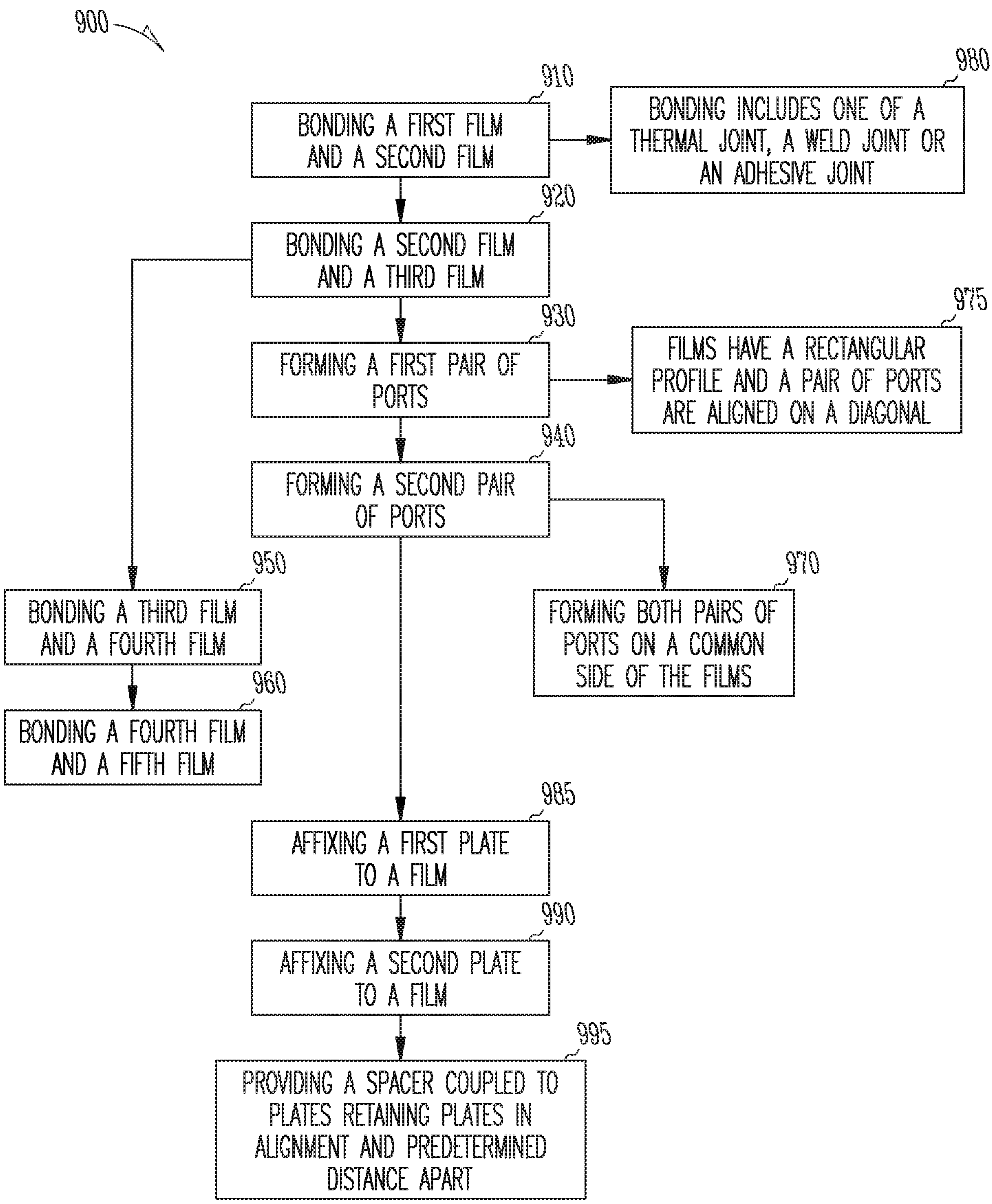
900
910
BONDING A FIRST FILM AND A SECOND FILM
980
BONDING INCLUDES ONE OF A THERMAL JOINT, A WELD JOINT OR AN ADHESIVE JOINT
920
BONDING A SECOND FILM AND A THIRD FILM
930
FORMING A FIRST PAIR OF PORTS
975
FILMS HAVE A RECTANGULAR PROFILE AND A PAIR OF PORTS ARE ALIGNED ON A DIAGONAL
940
FORMING A SECOND PAIR OF PORTS
950
BONDING A THIRD FILM AND A FOURTH FILM
960
BONDING A FOURTH FILM AND A FIFTH FILM
970
FORMING BOTH PAIRS OF PORTS ON A COMMON SIDE OF THE FILMS
985
AFFIXING A FIRST PLATE TO A FILM
990
AFFIXING A SECOND PLATE TO A FILM
995
PROVIDING A SPACER COUPLED TO PLATES RETAINING PLATES IN ALIGNMENT AND PREDETERMINED DISTANCE APART

*Fig.9*

## REFERENCES CITED IN THE DESCRIPTION



### Patent documents cited in the description


- US 60092715 **[0001]**
- US 4411310 A **[0005]**
- US 4744414 A **[0005]**
- EP 2508832 A1 **[0005]**