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(54) **BRAZED MICROCHANNEL HEAT EXCHANGER WITH THERMAL EXPANSION COMPENSATION**

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USPC **165/173**

(57) **ABSTRACT**

A brazed aluminum microchannel heat exchanger comprising a stack of alternating tubes and serpentine fins includes an expansion relief feature that accommodates uneven thermal expansion in the heat exchanger. The expansion relief feature provides the heat exchanger with sufficient structural support, at least during assembly, so that components of the heat exchanger can be firmly clamped in compression during a controlled-atmosphere brazing process. In some examples, the expansion relief feature is a gap or sliding engagement between adjacent headers of the heat exchanger. In addition or alternatively, the expansion relief feature comprises one or more slits cut into the serpentine fins after the brazing process, wherein each slit extends generally parallel to the tubes.

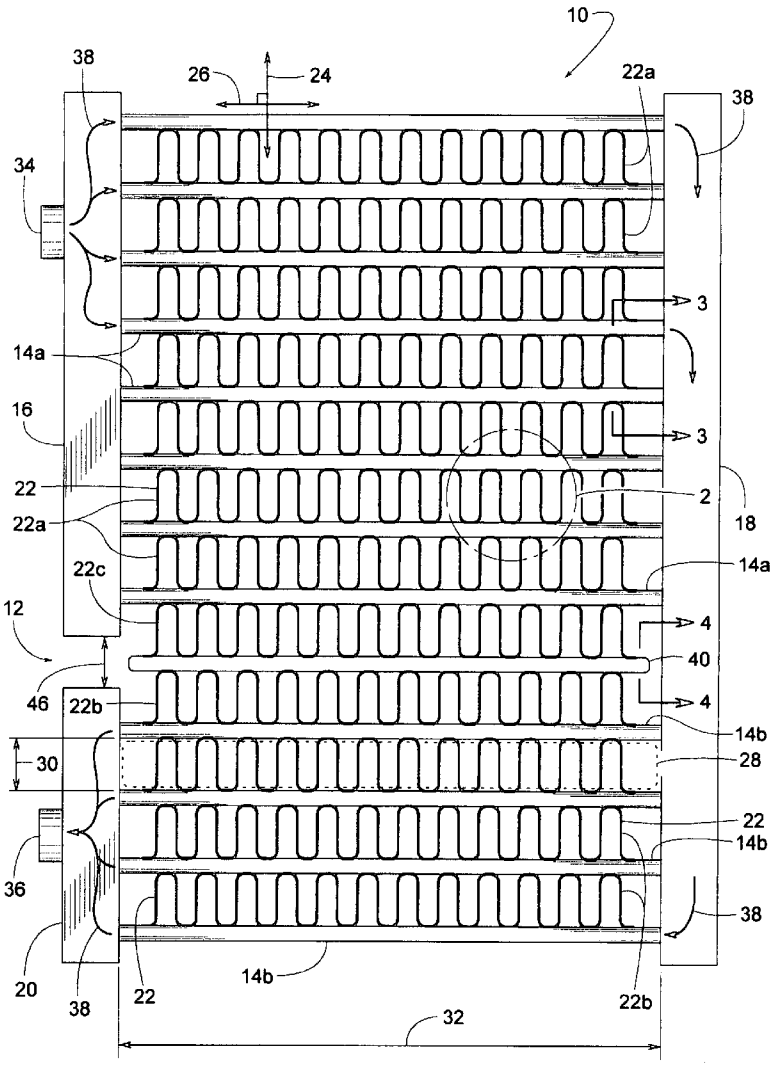


FIG. 1

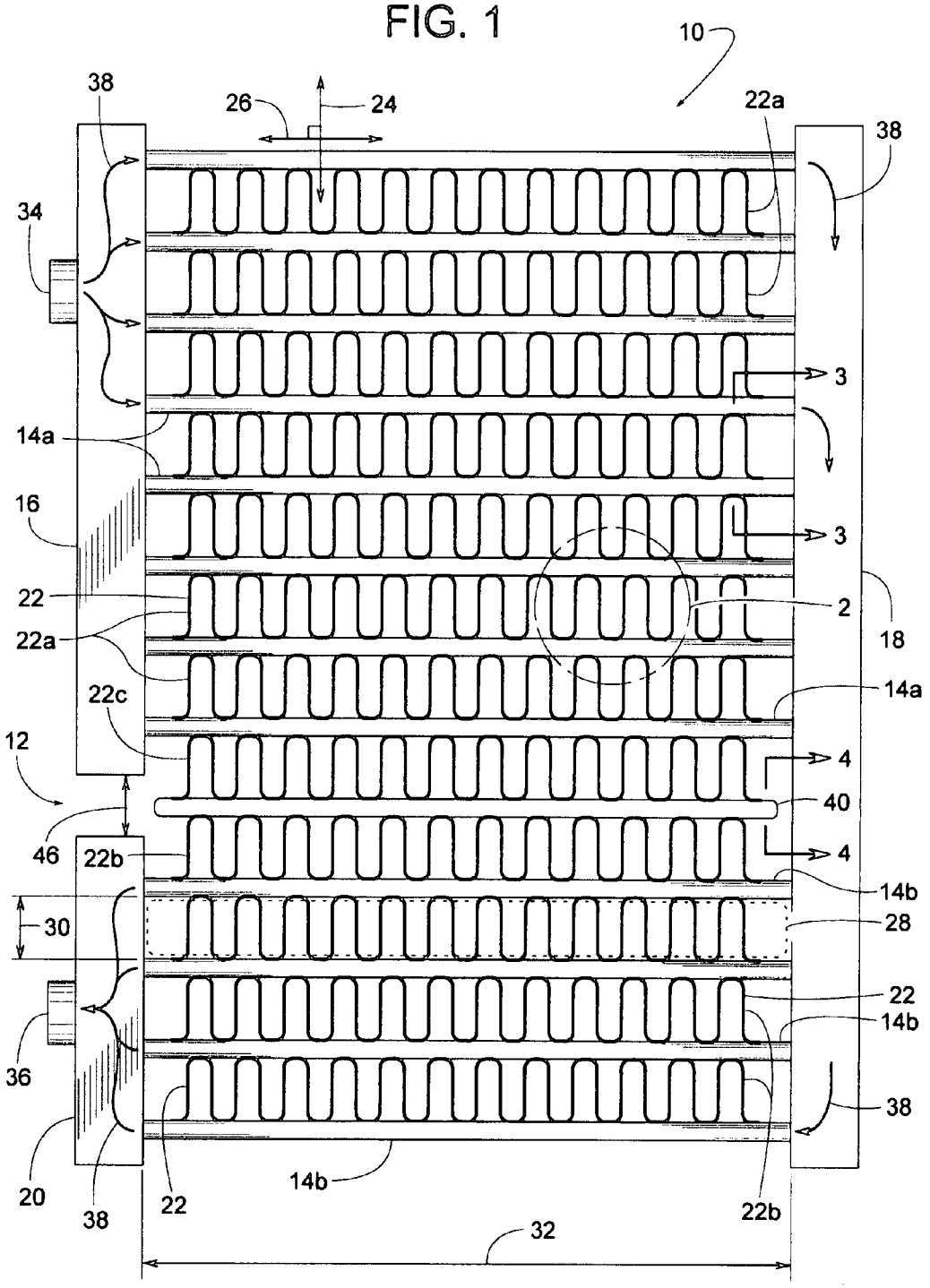

10
38
26
24
22a
38
34
3
14a
16
3
22
2
18
22a
22c
14a
12
4
40
46
22b
4
14b
30
28
22
14b
36
38
20
38
22
14b
22b
32

FIG. 2

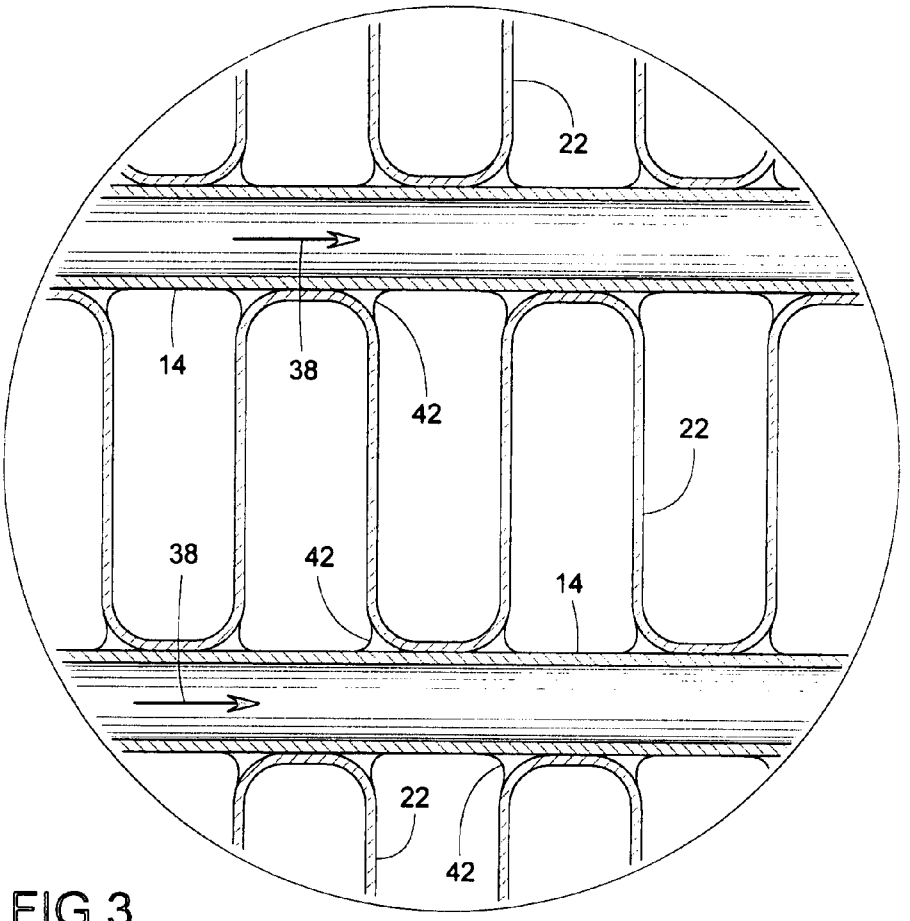


FIG.3

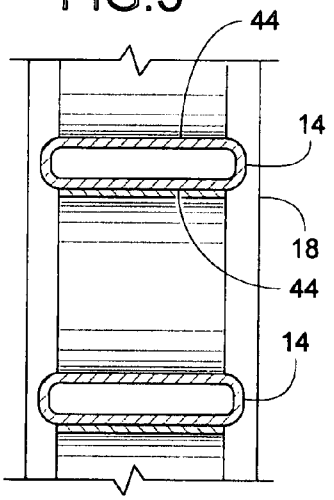


FIG. 4

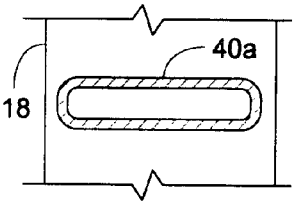


FIG. 5

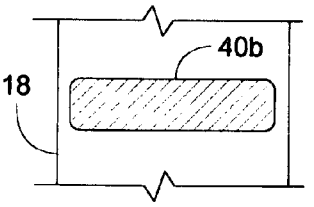


FIG. 6

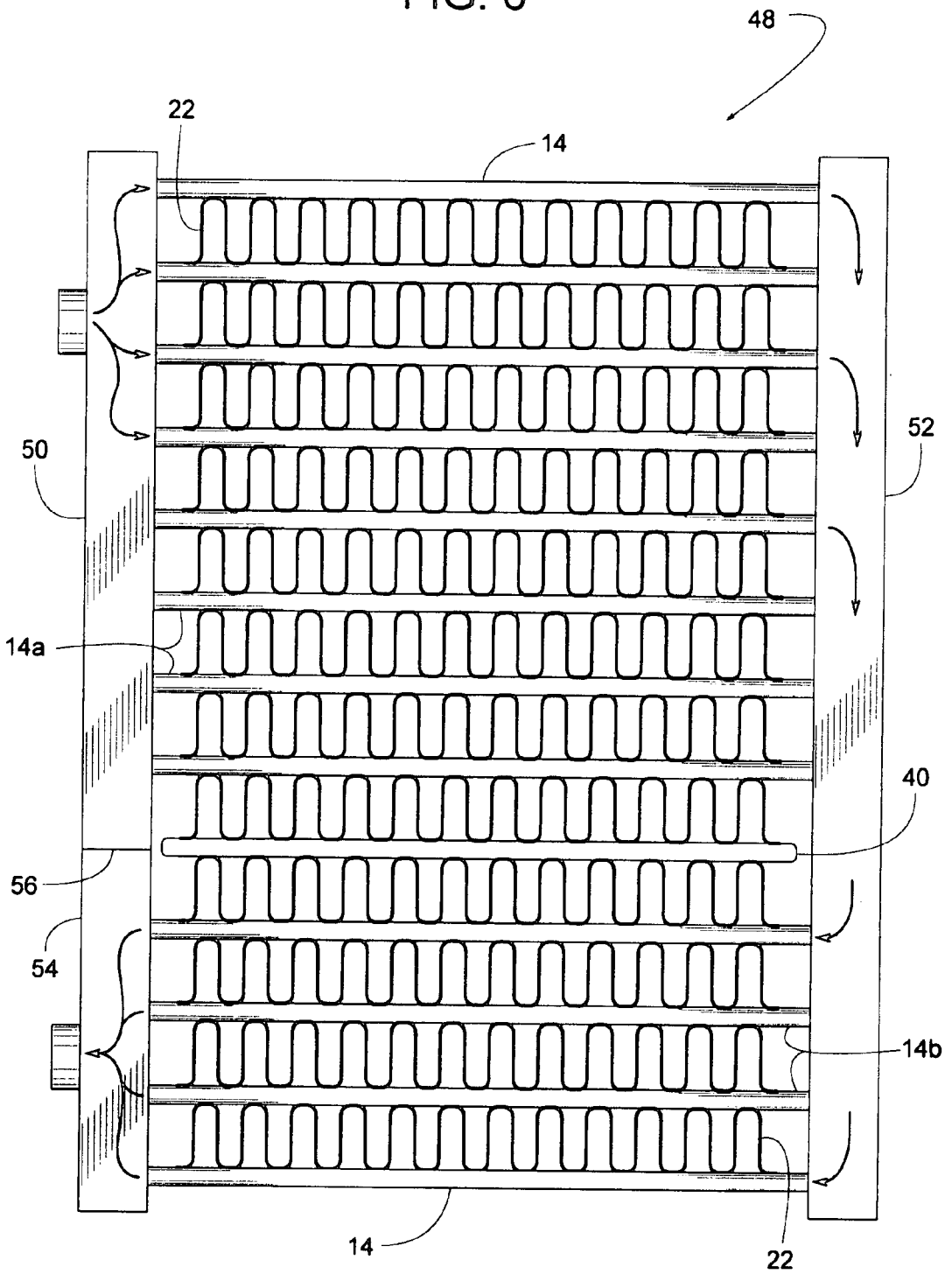


FIG. 7

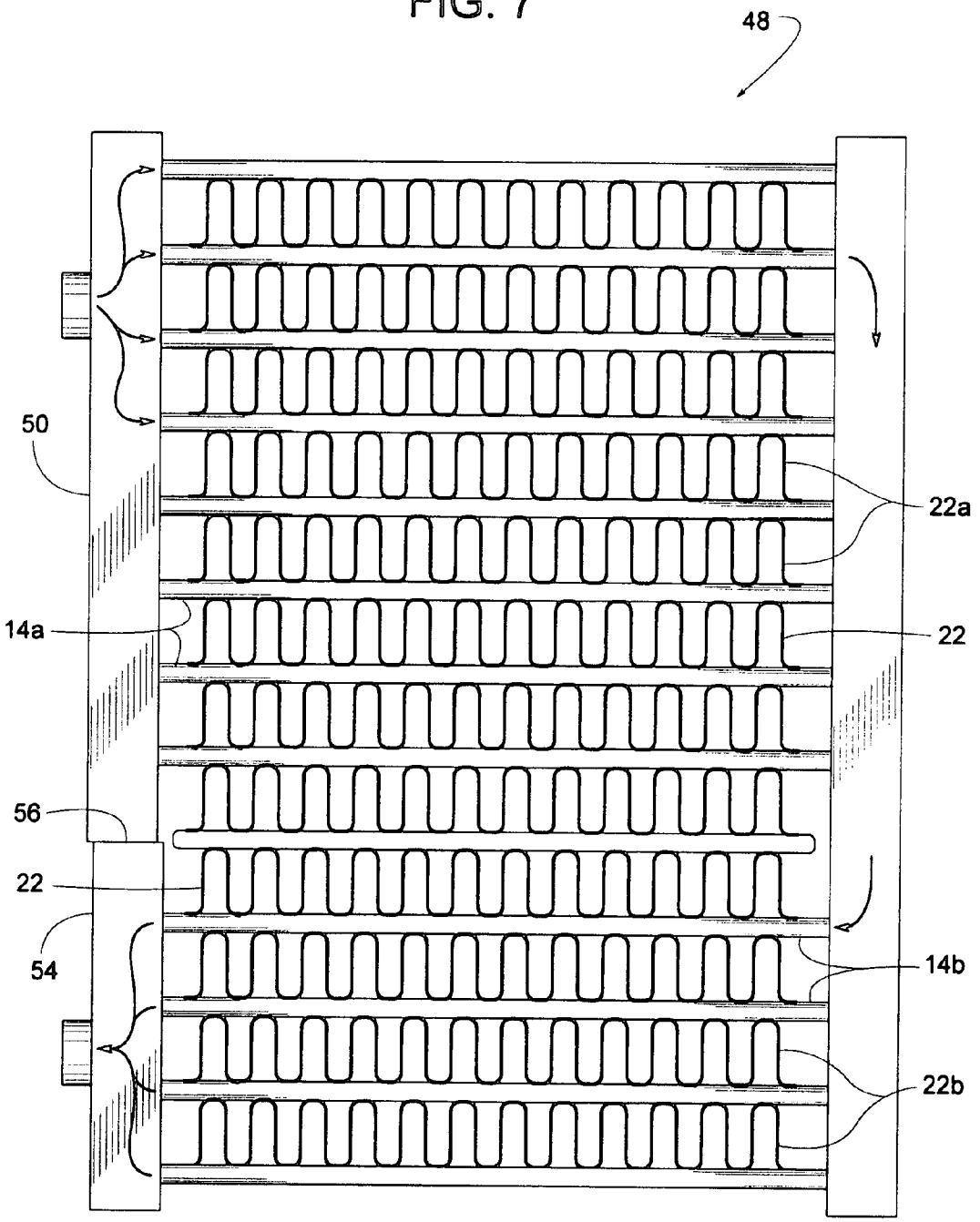


FIG. 8

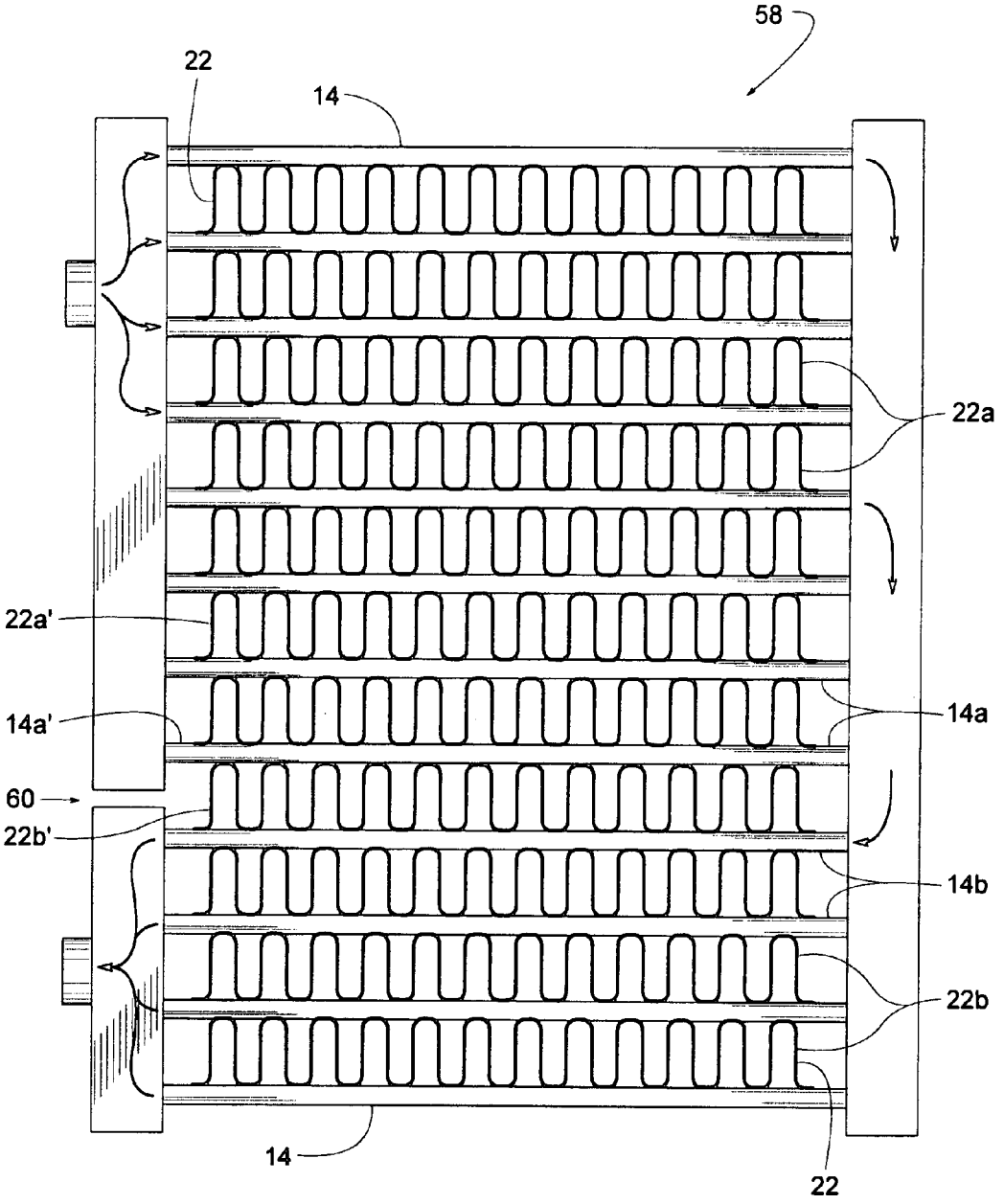


FIG. 9

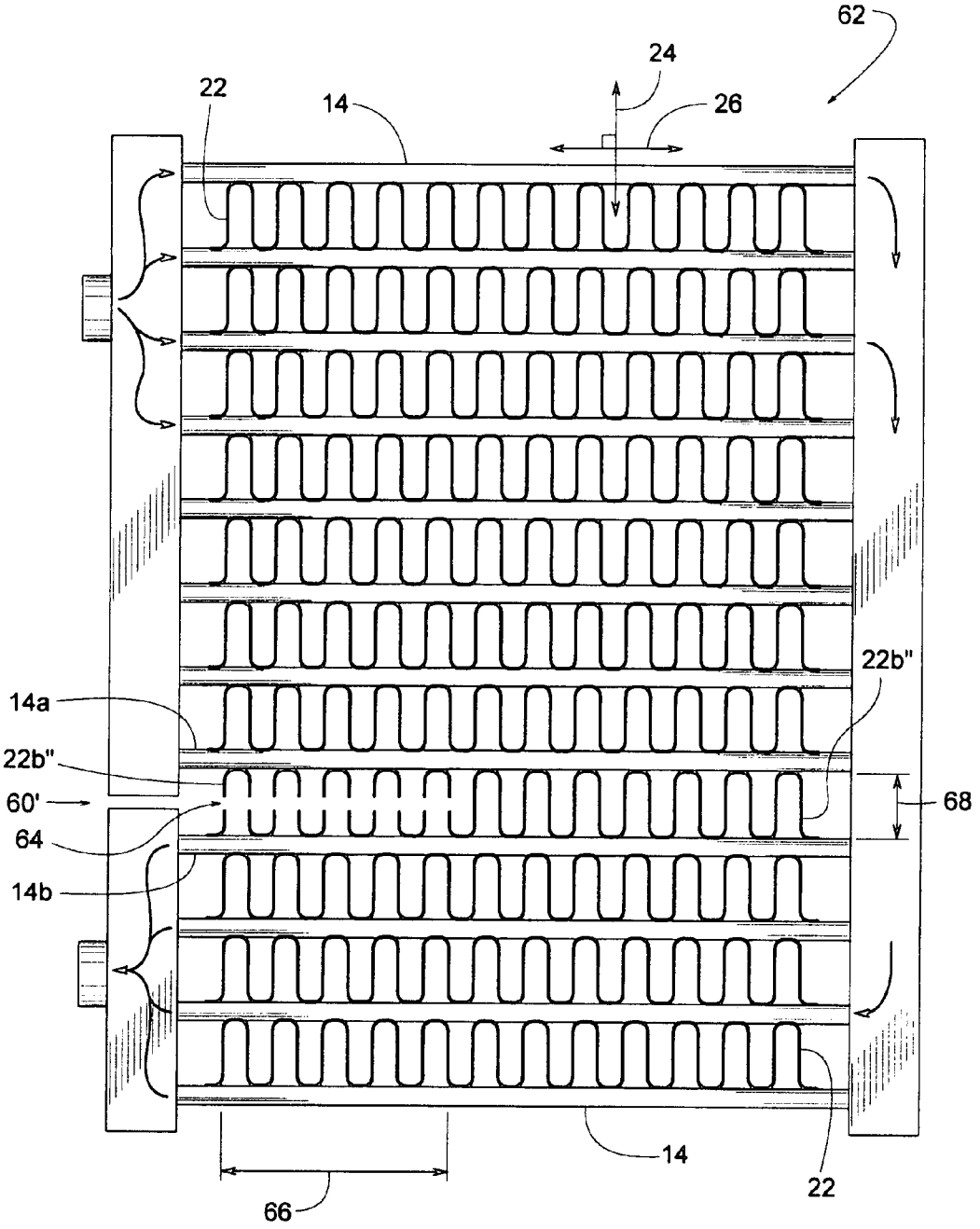


FIG. 10

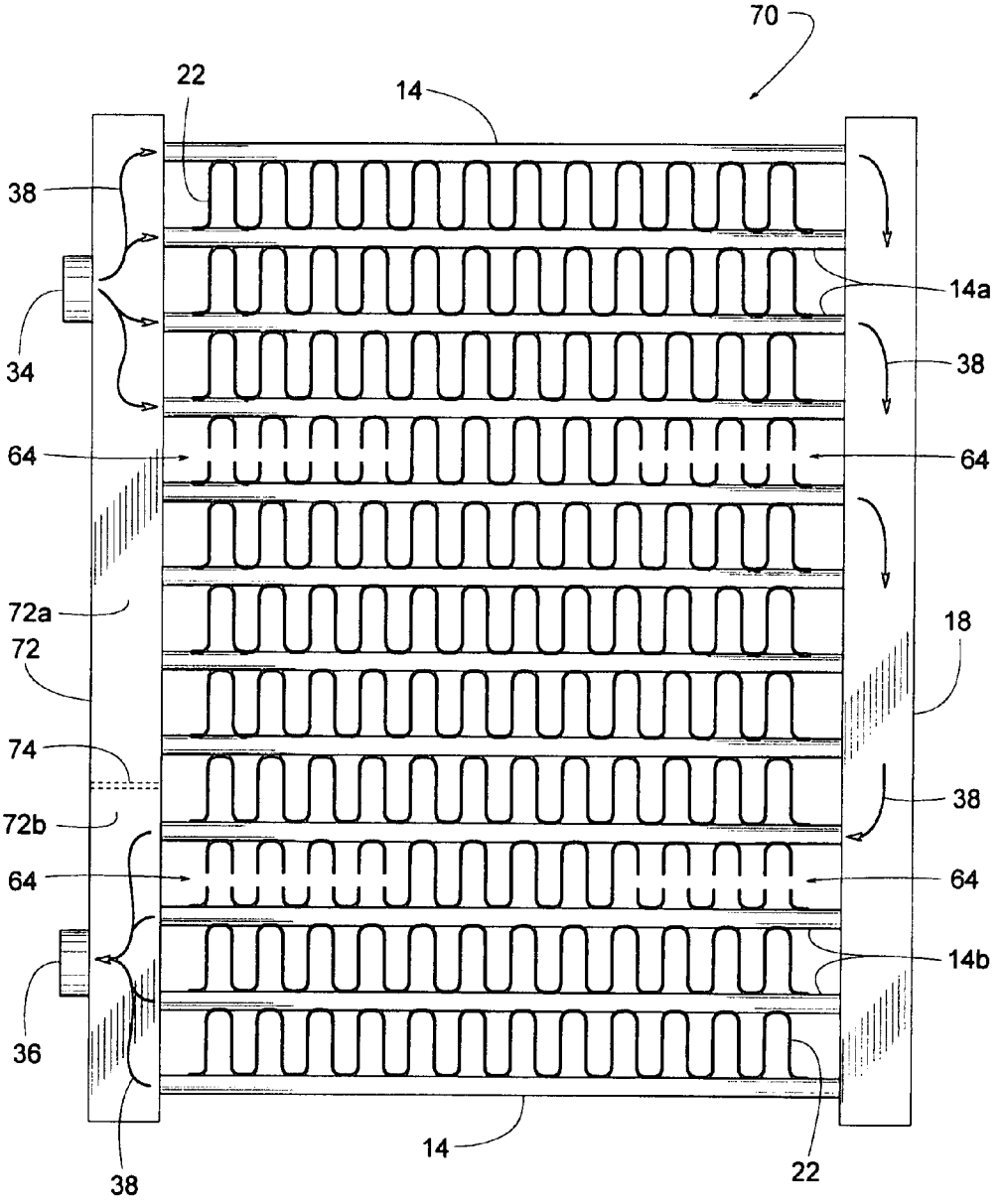


FIG. 11

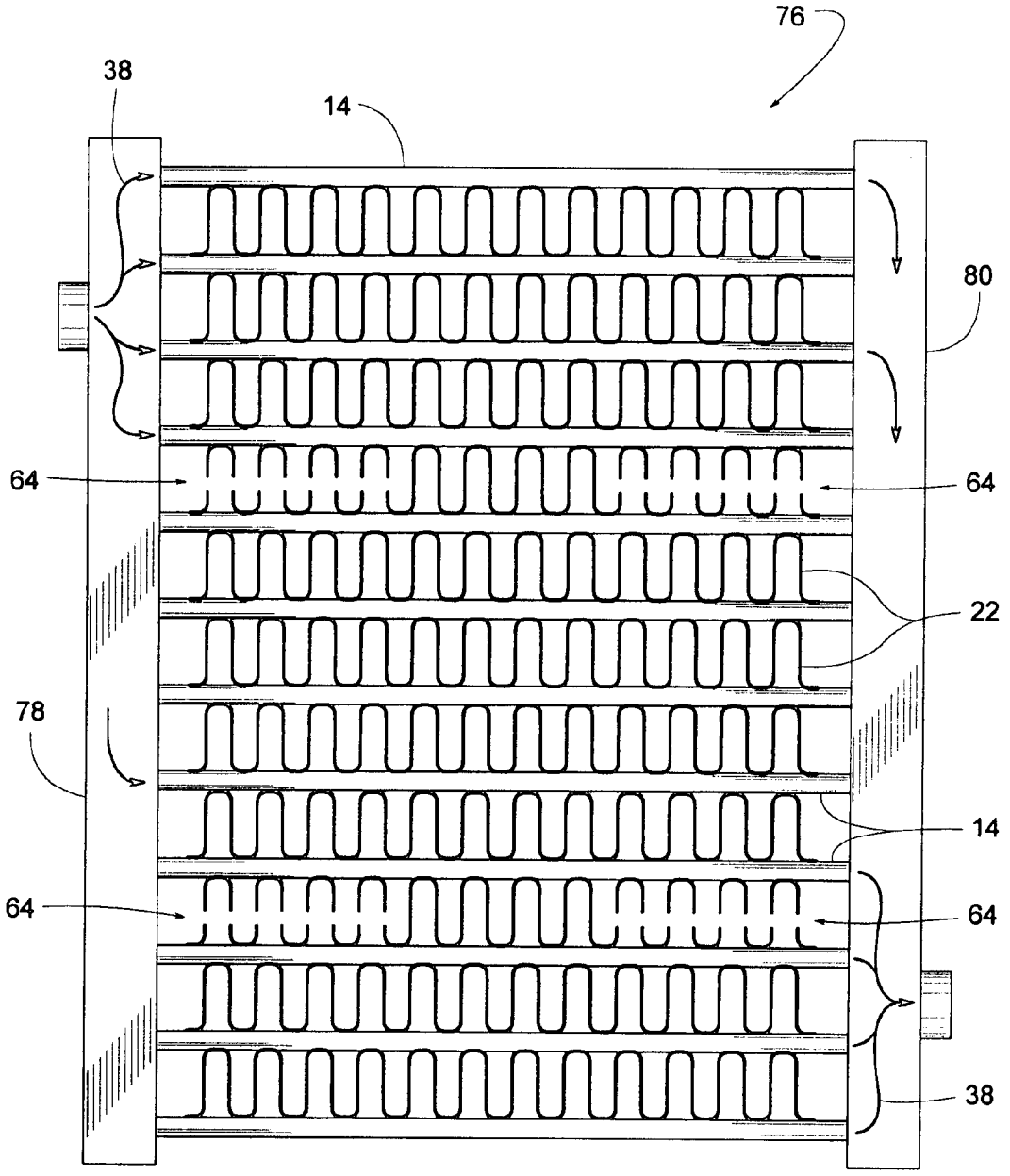
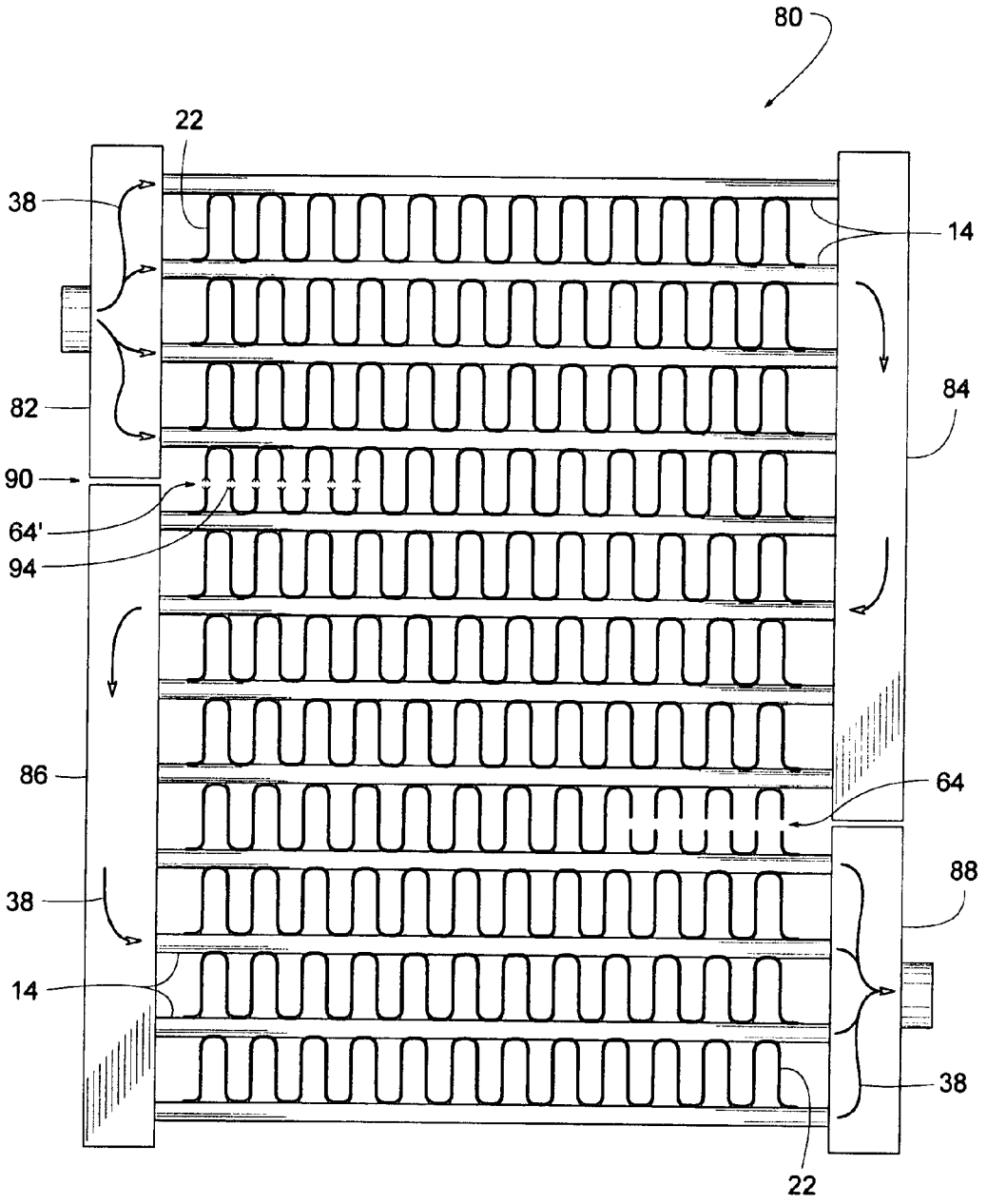


FIG. 12



BRAZED MICROCHANNEL HEAT EXCHANGER WITH THERMAL EXPANSION COMPENSATION

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The subject invention generally pertains to brazed microchannel heat exchangers and more specifically to a means for compensating for unequal thermal expansion in such heat exchangers.

[0003] 2. Description of Related Art

[0004] Microchannel heat exchangers often comprise a stack of alternating tubes and serpentine fins brazed between two or more headers. The tubes convey an internal fluid between the headers, while the serpentine fins promote heat transfer between the internal fluid and an external fluid passing across the heat exchanger.

SUMMARY OF THE INVENTION

[0005] It is an object of some embodiments of the invention to provide a brazed aluminum microchannel heat exchanger with an expansion relief feature that accommodates uneven thermal expansion in the heat exchanger.

[0006] Another object of some embodiments is to provide an expansion relief feature that has sufficient structural support, at least during assembly, so that components of the heat exchanger can be clamped in compression during a controlled-atmosphere brazing process.

[0007] Another object of some embodiments is to provide an expansion relief feature suitable for a heat exchanger comprising a stack of alternating tubes and serpentine fins.

[0008] In some embodiments the present invention provides a microchannel heat exchanger for conveying an internal fluid in heat transfer relationship with an external fluid. The microchannel heat exchanger includes a first header defining an inlet for the internal fluid to enter the microchannel heat exchanger, a second header, and a plurality of tubes each of which extend in a longitudinal direction between the first header and the second header. The plurality of tubes connect the first header in fluid communication with the second header to convey the internal fluid therebetween. The plurality of tubes include a first tube, a second tube and a third tube. The plurality of tubes are spaced apart from each other to define a plurality of spaces including a first space and a second space. The first space is between the first tube and the second tube, the second space is between the second tube and the third tube, and the second tube and the third tube are spaced apart over a separation distance. The microchannel heat exchanger also includes a plurality of serpentine fins interconnecting the plurality of tubes. The plurality of serpentine fins includes a first serpentine fin and a second serpentine fin. The first serpentine fin is contained in the first space between the first tube and the second tube. The second serpentine fin is contained in the second space between the second tube and the third tube. The second serpentine fin defines a slit extending in the longitudinal direction for a slit length that is greater than the separation distance between the second tube and the third tube.

[0009] In some embodiments the present invention provides a microchannel heat exchanger for conveying an internal fluid in heat transfer relationship with an external fluid. The microchannel heat exchanger includes a first header defining an inlet for the internal fluid to enter the microchannel heat exchanger, a second header, and a third header adjacent to the first header. The microchannel heat exchanger also includes a first plurality of tubes each of which extend in a longitudinal direction. The first plurality of tubes connect the first header in fluid communication with the second header to convey the internal fluid from the first header to the second header. The microchannel heat exchanger also includes a second plurality of tubes each of which extend in the longitudinal direction. The second plurality of tubes connect the second header in fluid communication with the third header to convey the internal fluid from the second header to the third header. The microchannel heat exchanger also includes a first plurality of serpentine fins interconnecting in a lateral direction the first plurality of tubes, wherein the lateral direction is generally perpendicular to the longitudinal direction. The microchannel heat exchanger also includes a second plurality of serpentine fins interconnecting in the lateral direction the second plurality of tubes. The microchannel heat exchanger also includes a braze material bonding the first header to the first plurality of tubes, bonding the second header to the first plurality of tubes, bonding the second plurality of tubes to the second header, bonding the second plurality of tubes to the third header, bonding the first plurality of serpentine fins to the first plurality of tubes, and bonding the second plurality of serpentine fins to the second plurality of tubes. The microchannel heat exchanger also includes an expansion relief feature existing between the first header and the second header, the expansion relief feature accommodating relative movement in the longitudinal direction between the first header and the third header in response to a difference in longitudinal thermal expansion of the first plurality of tubes relative to the second plurality of tubes.

[0010] In some embodiments the present invention provides a microchannel heat exchanger for conveying an internal fluid in heat transfer relationship with an external fluid. The microchannel heat exchanger includes a first header defining an inlet for the internal fluid to enter the microchannel heat exchanger, a second header, a third header adjacent to the first header, and a first plurality of tubes each of which extend in a longitudinal direction. The first plurality of tubes connect the first header in fluid communication with the second header to convey the internal fluid from the first header to the second header. The microchannel heat exchanger also includes a second plurality of tubes each of which extend in the longitudinal direction. The second plurality of tubes connect the second header in fluid communication with the third header to convey the internal fluid from the second header to the third header. The microchannel heat exchanger also includes a first plurality of serpentine fins interconnecting in a lateral direction the first plurality of tubes, wherein the lateral direction is generally perpendicular to the longitudinal direction. The microchannel heat exchanger also includes a second plurality of serpentine fins interconnecting in the lateral direction the second plurality of tubes. The microchannel heat exchanger also includes a braze material bonding the first header to the first plurality of tubes, bonding the second header to the first plurality of tubes, bonding the second plurality of tubes to the second header, bonding the second plurality of tubes to the third header, bonding the first plurality of serpentine fins to the first plurality of tubes, and bonding the second plurality of serpentine fins to the second plurality of tubes. The microchannel heat exchanger also includes an expansion relief feature existing between the first header and the second header. The expansion relief feature accommo-

dates relative movement in the longitudinal direction between the first header and the third header in response to a difference in longitudinal thermal expansion of the first plurality of tubes relative to the second plurality of tubes. The microchannel heat exchanger also includes an elongate member interposed between the first plurality of tubes and the second plurality of tubes. The elongate member is elongated in the longitudinal direction. The elongate member is shorter than each of the first plurality of tubes. The elongate member conveys substantially none of the internal fluid. The microchannel heat exchanger also includes a first serpentine fin, and the braze material joins the first plurality of tubes to the elongate member. The microchannel heat exchanger also includes a second serpentine fin, and the braze material joins the second plurality of tubes to the elongate member.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a front view of an example microchannel heat exchanger with an expansion relief feature.

[0012] FIG. **2** is an enlarged cross-sectional view of the area identified by circle-**2** of FIG. **1**.

[0013] FIG. **3** is a cross-sectional view taken along line **3**-**3** of FIG. **1**.

[0014] FIG. **4** is a cross-sectional view taken along line **4**-**4** of FIG. **1**.

[0015] FIG. **5** is a cross-sectional view similar to FIG. **4** but showing the cross section of an alternate elongate member.

[0016] FIG. **6** is a front view of another example microchannel heat exchanger with an expansion relief feature.

[0017] FIG. **7** is a front view similar to FIG. **6** but showing the expansion relief feature accommodating uneven thermal expansion of the heat exchanger.

[0018] FIG. **8** is a front view of another example microchannel heat exchanger with an expansion relief feature.

[0019] FIG. **9** is a front view of another example microchannel heat exchanger with an expansion relief feature.

[0020] FIG. **10** is a front view of another example microchannel heat exchanger with an expansion relief feature.

[0021] FIG. **11** is a front view of another example microchannel heat exchanger with an expansion relief feature.

[0022] FIG. **12** is a front view of another example microchannel heat exchanger with an expansion relief feature.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0023] FIG. **1**, with additional reference to FIGS. **2**-**5**, illustrates one example of a microchannel heat exchanger **10** that includes an expansion relief feature **12** for accommodating uneven thermal expansion in heat exchanger **10**.

[0024] In the illustrated example, heat exchanger **10** comprises a first plurality of tubes **14***a* extending between a first header **16** (manifold) and a second header **18**, a second plurality of tubes **14***b* extending between second header **18** and a third header **20**, a first plurality of serpentine fins **22***a* stacked and bonded (e.g., brazed) in an alternating arrangement with the first plurality of tubes **14***a*, and a second plurality of serpentine fins **22***b* stacked and bonded in an alternating arrangement with the second plurality of tubes **14***b*. The term, "serpentine," means that the fin is wavy with peaks and valleys (e.g., sine wave, square wave, and various modifications thereof).

[0025] In the illustrated examples, the peaks and valleys of serpentine fins **22** are brazed or otherwise bonded to adjacent tubes **14**, whereby fins **22** interconnect in a lateral direction **24** the plurality of tubes **14**. Each fin **22** extends farther in a longitudinal direction **26** (parallel to tubes **14**) than in lateral direction **24**. The general expression, "the serpentine fins are stacked in an alternating arrangement with the tubes," means that each fin **22** is contained within its own space **28** between two tubes and that the tubes do not pass through the fin. Thus, a serpentine fin **22** in one space **28** is separated from another serpentine fin **22** in another space **28**, and heat exchanger **10** has a plurality of spaces **28**, e.g., a first space, a second space, a third space, etcetera. Each space **28** is defined in lateral direction **24** by two adjacent tubes **14** that are spaced apart by a separation distance **30**, and each space **28** is further defined in longitudinal direction **26** by a spaced-apart distance **32** between headers at opposite ends of tubes **14**.

[0026] In this example, first header **16** has an inlet **34**, and third header **20** has an outlet **36**. An internal fluid **38** (e.g., refrigerant, water, glycol, etc.) enters first header **16** through inlet **34**, and the first plurality of tubes **14***a* convey fluid **38** to second header **18**. The second plurality of tubes **14***b* convey fluid **38** from second header **18** to third header **20**, and outlet **36** releases fluid **38** out from within third header **20**. Inlet **34** and outlet **36** can be connected to various elements of a system that incorporates heat exchanger **10**. Such a system, for example, could be an air conditioner or heat pump where heat exchanger **10** functions as an evaporator or a condenser.

[0027] Fins **22** (i.e., fins **22***a* and **22***b*) are thermally conductive to promote heat transfer between internal fluid **38** flowing through tubes **14** (i.e., tubes **14***a* and **14***b*, which are also thermally conductive) and an external fluid (e.g., air) flowing across the external surfaces of fins **22** and tubes **14**. A fan, blower or some other known means can be used for forcing air or some other external fluid across the external surfaces of heat exchanger **10**.

[0028] Although the actual structure of heat exchanger **10** may vary, in some examples, tubes **14**; fins **22**; headers **16**, **18** and **20**; and an elongate member **40** (to be explained later) are made primarily of common aluminum (and/or alloys thereof) and are joined or bonded by a common braze material **42**. In some examples, at least some of the aforementioned parts of heat exchanger **10** are coated (e.g., plated, clad, etc.) with a thin layer of braze material **42** (e.g., aluminum fin stock clad with braze alloy) so that after the parts are assembled in a desired arrangement, the entire assembly is heated in a controlled atmosphere (e.g., an extreme vacuum) until braze material **42** melts, flows and subsequently bonds the parts together. Tube-to-fin heat transfer is enhanced by providing tubes **14** with substantially flat surfaces **44**, as shown in FIG. **3**.

[0029] In the example shown in FIG. **1**, expansion relief feature **12** is first header **16** being spaced apart from second header **20** to define a gap **46** therebetween. Gap **46** allows relative movement between headers **16** and **20** and thus allows tubes **14***a* to expand more or less than tubes **14***b* in longitudinal direction **26**. Gap **46** might also accommodate differences in thermal expansion in a vertical direction (vertical as viewed in FIG. **1**). A difference in thermal expansion in heat exchanger **10** can be caused by the temperature of internal fluid **38** increasing or decreasing as fluid **38** flows through heat exchanger **10**.

[0030] To provide some structural support in the general area of gap **46** and expansion relief feature **12**, heat exchanger **10** has elongate member **40** brazed or otherwise bonded between the two sets of tubes **14***a* and **14***b*. In examples where

elongate member **40** is brazed to tubes oo**14***aoa* and **14***b*, structural support in the area of expansion relief feature **12** is particularly important during the brazing process. Elongate member **40** can be of various cross-sectional areas, such as those shown in FIGS. **4** and **5**. FIG. **4** shows an example elongate member **40***a* with a tubular cross-sectional area (similar to that of tube **14**); however, elongate member **40***a* does not convey any internal fluid **38**. FIG. **5** shows an example elongate member **40***b* as a solid bar with a generally rectangular cross-sectional area. In some examples, elongate member **40** is shorter than tubes **14** because there may be no need for elongate member **40** to contact any of the headers.

[0031] In another example, shown in FIGS. **6** and **7**, a microchannel heat exchanger **48** includes a first header **50**, second header **52**, and a third header **54**. The first and third headers **50** and **54** are in sliding abutment with each other to provide an expansion relief feature **56** therebetween. In comparison to FIG. **6**, FIG. **7** shows tubes **14***a* being longer than tubes **14***b* due to a difference in thermal expansion of tubes **14***a* relative to tubes **14***b*.

[0032] In another example, shown in FIG. **8**, a microchannel heat exchanger **58** is similar to heat exchanger **10** of FIG. **1**; however, elongate member **40** is eliminated in heat exchanger **58** by placing tubes **14***a* closer to tubes **14***b*. Instead of elongate member **40** and an intermediate serpentine fin **22***c* (FIG. **1**), a lowermost tube **14***a*' is all that couples the lowermost fin **22***a*' to an uppermost fin **22***b*'. Heat exchanger **58** still includes an expansion relief feature **60** similar or identical to expansion relief features **12** and **56**. In some examples, as shown in a microchannel heat exchanger **62** of FIG. **9**, a slit **64** in an uppermost fin **22***b*" is added to expansion relief feature **60** (FIG. **8**) to create a more flexible expansion relief feature **60**'. In some cases, slit **64** is created by sawing into fin **22***b*' to produce fin **22***b*". To provide heat exchanger **62** with sufficient flexibility at feature **60**', slit **64** has a length **66** in longitudinal direction **26** that is greater than a separation distance **68** between tubes **14***a* and **14***b*. Length **66** of slit **64** preferably is more than ten times as great as separation distance **68**. In some examples, length **66** is about 30 times as great as separation distance **68**.

[0033] FIG. **10** shows an example microchannel heat exchanger **70** wherein one or more slits **64** in a plurality of serpentine fins **22** is sufficient in itself to provide heat exchanger **70** with an expansion relief feature (slits **64**). In some examples, fins **22** are the same as others mentioned herein, except for slits **64** being cut into them. In the example of FIG. **10**, instead of two separate headers **16** and **20**, the two are combined in a single header **72** with a block-off **74** or plug that divides header **72** into two chambers **74***a* and **74***b*. Fluid **38** enters chamber **72***a* through inlet **34**, and the first plurality of tubes **14***a* convey fluid **38** to header **18**. The second plurality of tubes **14***b* convey fluid **38** from header **18** to chamber **72***b*, and outlet **36** releases fluid **38** out from within chamber **72***b*. Since fluid **38** makes two passes across the width of heat exchanger **70**, it can be considered a two-pass heat exchanger.

[0034] A single-pass version is shown in FIG. **11**. In this example, a heat exchanger **76** includes a single chamber inlet header **78** without block-off **74** and a single chamber outlet header **80**. Tubes **14** convey fluid **38** in a single pass from inlet header **78** to outlet header **80**. Slits **64** (any number of slits, one or more) serve as the heat exchanger's expansion relief feature.

[0035] Any of the example heat exchangers shown in FIGS. **1** and **6-11** can be readily modified to provide any number of passes. FIG. **12**, for example, shows a microchannel heat exchanger **80** that includes a first header **82**, a second header **84**, a third header **86** and a fourth header **88** that makes heat exchanger **80** a three-pass heat exchanger. The upper four tubes **14** convey fluid **38** from first header **82** to second header **84** for a first pass, the middle four tubes **14** convey fluid **38** from second header **84** to third header **86** for a second pass, and the lower four tubes **14** convey fluid **38** from third header **86** to fourth header **88** for a third pass. One or more expansion relief features are provided by a slit **64**', a gap **90** (or sliding engagement) between headers **82** and **86**, slit **64**, a gap **92** (or sliding engagement) between headers **84** and **88**, and/or various combinations thereof. Example slit **64**' has frayed/jagged edges **94** to promote heat transfer in that area. Such frayed/jagged edges can be the result of cutting burrs from a conventional sawing process.

[0036] It should be noted that when one header is stated as being "adjacent" to another header, that means the two headers are in proximity with each other but not necessarily in contact with each other.

[0037] Although the invention is described with respect to a preferred embodiment, modifications thereto will be apparent to those of ordinary skill in the art. The scope of the invention, therefore, is to be determined by reference to the following claims:

1. A microchannel heat exchanger for conveying an internal fluid in heat transfer relationship with an external fluid, the microchannel heat exchanger comprising:

a first header defining an inlet for the internal fluid to enter the microchannel heat exchanger;

a second header;

a plurality of tubes each of which extend in a longitudinal direction between the first header and the second header, the plurality of tubes connecting the first header in fluid communication with the second header to convey the internal fluid therebetween, the plurality of tubes includes a first tube, a second tube and a third tube, the plurality of tubes being spaced apart from each other to define a plurality of spaces including a first space and a second space, the first space being between the first tube and the second tube, the second space being between the second tube and the third tube, and the second tube and the third tube being spaced apart over a separation distance; and

a plurality of serpentine fins interconnecting the plurality of tubes, the plurality of serpentine fins including a first serpentine fin and a second serpentine fin, the first serpentine fin being contained in the first space between the first tube and the second tube, the second serpentine fin being contained in the second space between the second tube and the third tube, the second serpentine fin defining a slit extending in the longitudinal direction for a slit length that is greater than the separation distance between the second tube and the third tube.

2. The microchannel heat exchanger of claim **1**, wherein the slit length is more than ten times as great as the separation distance between the second tube and the third tube.

3. The microchannel heat exchanger of claim **1**, wherein the slit length is shorter than a spaced-apart distance between the first header and the second header.

4. The microchannel heat exchanger of claim **1**, wherein the plurality of serpentine fins define a plurality of slits similar to the slit defined by the second serpentine fin.

5. The microchannel heat exchanger of claim 1, further comprising a braze material bonding the second serpentine fin to the first tube and the second tube.

6. The microchannel heat exchanger of claim 1, wherein the plurality of tubes include a plurality of substantially flat surfaces attached to the plurality of serpentine fins.

7. A microchannel heat exchanger for conveying an internal fluid in heat transfer relationship with an external fluid, the microchannel heat exchanger comprising:

a first header defining an inlet for the internal fluid to enter the microchannel heat exchanger;

a second header;

a third header adjacent to the first header;

a first plurality of tubes each of which extend in a longitudinal direction, the first plurality of tubes connecting the first header in fluid communication with the second header to convey the internal fluid from the first header to the second header;

a second plurality of tubes each of which extend in the longitudinal direction, the second plurality of tubes connecting the second header in fluid communication with the third header to convey the internal fluid from the second header to the third header;

a first plurality of serpentine fins interconnecting in a lateral direction the first plurality of tubes, wherein the lateral direction is generally perpendicular to the longitudinal direction;

a second plurality of serpentine fins interconnecting in the lateral direction the second plurality of tubes;

a braze material bonding the first header to the first plurality of tubes, bonding the second header to the first plurality of tubes, bonding the second plurality of tubes to the second header, bonding the second plurality of tubes to the third header, bonding the first plurality of serpentine fins to the first plurality of tubes, and bonding the second plurality of serpentine fins to the second plurality of tubes; and

an expansion relief feature existing between the first header and the second header, the expansion relief feature accommodating relative movement in the longitudinal direction between the first header and the third header in response to a difference in longitudinal thermal expansion of the first plurality of tubes relative to the second plurality of tubes.

8. The microchannel heat exchanger of claim 7, wherein the expansion relief feature is the first header being in sliding abutment with the second header.

9. The microchannel heat exchanger of claim 7, wherein the expansion relief feature is the first header being spaced apart from the second header to define a gap therebetween.

10. The microchannel heat exchanger of claim 7, further comprising a serpentine fin interposed between the first plurality of tubes and the second plurality of tubes, the serpentine fin defining a slit extending in the longitudinal direction for a slit length greater than a separation distance between the first plurality of tubes and the second plurality of tubes.

11. The microchannel heat exchanger of claim 7, further comprising:

an elongate member interposed between the first plurality of tubes and the second plurality of tubes, the elongate member being elongated in the longitudinal direction, the elongate member being distinguishable from each of the first plurality of tubes by virtue of at least one of length and cross-sectional area;

a first serpentine fin and the braze material joining the first plurality of tubes to the elongate member; and

a second serpentine fin and the braze material joining the second plurality of tubes to the elongate member.

12. The microchannel heat exchanger of claim 11, wherein the elongate member is tubular but conveys substantially none of the internal fluid.

13. The microchannel heat exchanger of claim 11, wherein the elongate member is a solid bar.

14. The microchannel heat exchanger of claim 11, wherein the elongate member is shorter than each of the first plurality of tubes.

15. The microchannel heat exchanger of claim 7, wherein the plurality of tubes include a plurality of substantially flat surfaces attached to the plurality of serpentine fins.

16. A microchannel heat exchanger for conveying an internal fluid in heat transfer relationship with an external fluid, the microchannel heat exchanger comprising:

a first header defining an inlet for the internal fluid to enter the microchannel heat exchanger;

a second header;

a third header adjacent to the first header;

a first plurality of tubes each of which extend in a longitudinal direction, the first plurality of tubes connecting the first header in fluid communication with the second header to convey the internal fluid from the first header to the second header;

a second plurality of tubes each of which extend in the longitudinal direction, the second plurality of tubes connecting the second header in fluid communication with the third header to convey the internal fluid from the second header to the third header;

a first plurality of serpentine fins interconnecting in a lateral direction the first plurality of tubes, wherein the lateral direction is generally perpendicular to the longitudinal direction;

a second plurality of serpentine fins interconnecting in the lateral direction the second plurality of tubes;

a braze material bonding the first header to the first plurality of tubes, bonding the second header to the first plurality of tubes, bonding the second plurality of tubes to the second header, bonding the second plurality of tubes to the third header, bonding the first plurality of serpentine fins to the first plurality of tubes, and bonding the second plurality of serpentine fins to the second plurality of tubes;

an expansion relief feature existing between the first header and the second header, the expansion relief feature accommodating relative movement in the longitudinal direction between the first header and the third header in response to a difference in longitudinal thermal expansion of the first plurality of tubes relative to the second plurality of tubes;

an elongate member interposed between the first plurality of tubes and the second plurality of tubes, the elongate member being elongated in the longitudinal direction, the elongate member being shorter than each of the first plurality of tubes, the elongate member conveying substantially none of the internal fluid;

a first serpentine fin and the braze material joining the first plurality of tubes to the elongate member; and

a second serpentine fin and the braze material joining the second plurality of tubes to the elongate member.

17. The microchannel heat exchanger of claim **16**, wherein the expansion relief feature is the first header being in sliding abutment with the second header.

18. The microchannel heat exchanger of claim **16**, wherein the expansion relief feature is the first header being spaced apart from the second header to define a gap therebetween.

19. The microchannel heat exchanger of claim **16**, wherein the elongate member is tubular.

20. The microchannel heat exchanger of claim **16**, wherein the elongate member is a solid bar.

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