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(54) INTEGRATED SUPPLY AND RETURN MANIFOLD FOR TUBE-IN-TUBE HEAT TRANSFER

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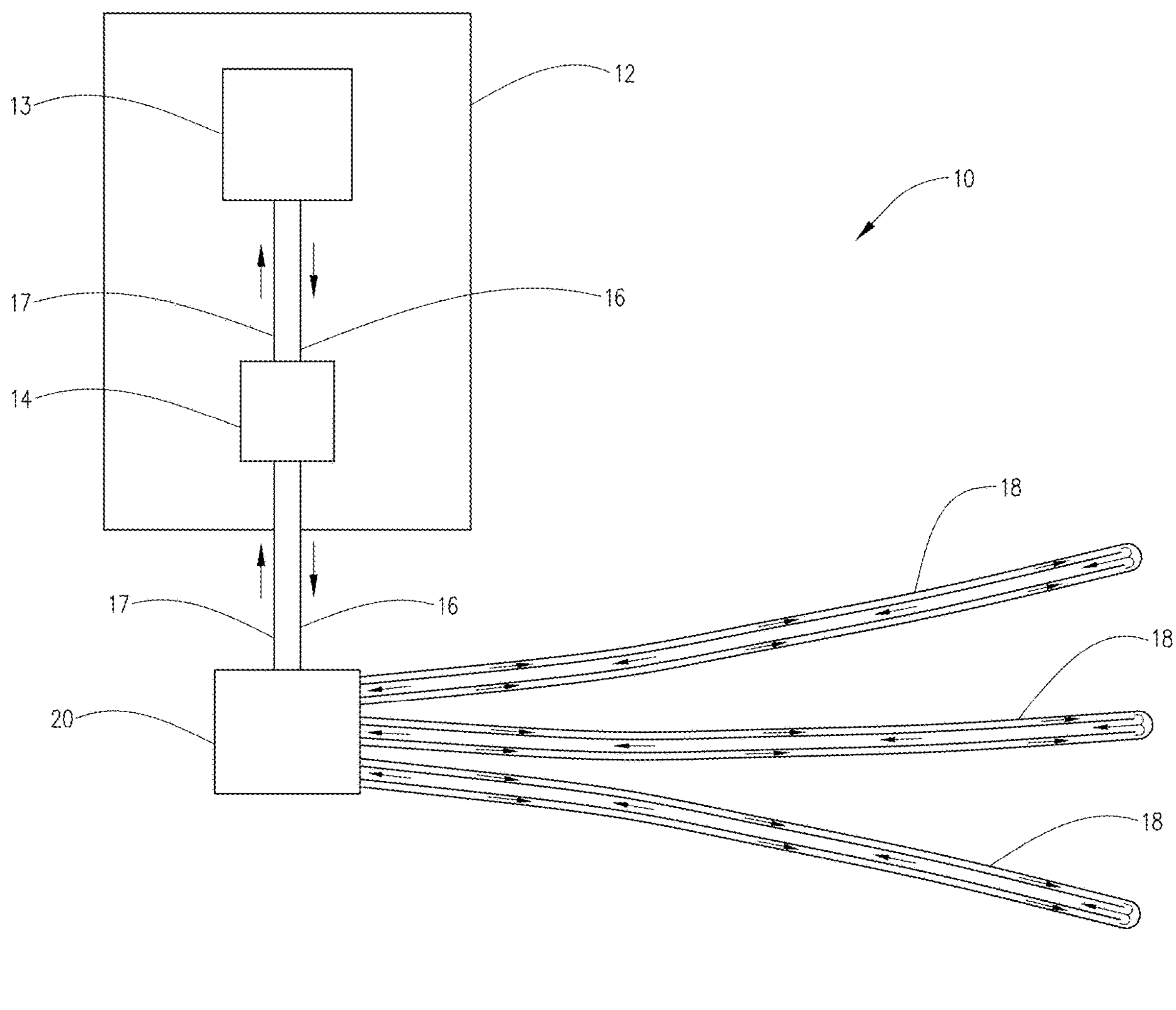
(52) **U.S. Cl.**
CPC ............ ***F28F 9/0202*** (2013.01); ***F28D 7/106*** (2013.01); ***F28D 7/12*** (2013.01)

(57) **ABSTRACT**

A manifold having integrated distribution and collection manifolds in a single component. The integrated distribution and collection manifolds provide balanced flow and pressure between the distribution and collection manifolds.



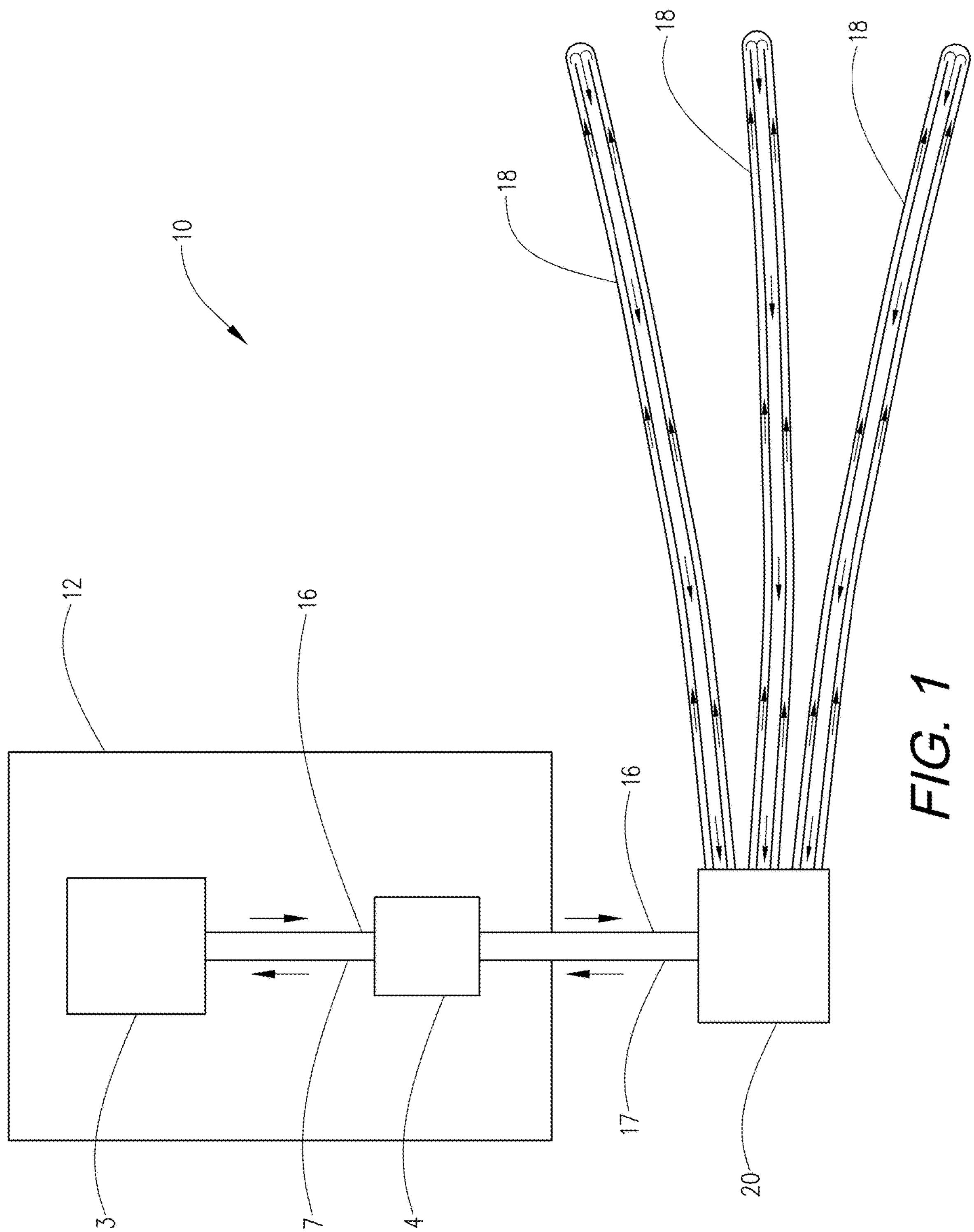



FIG. 1

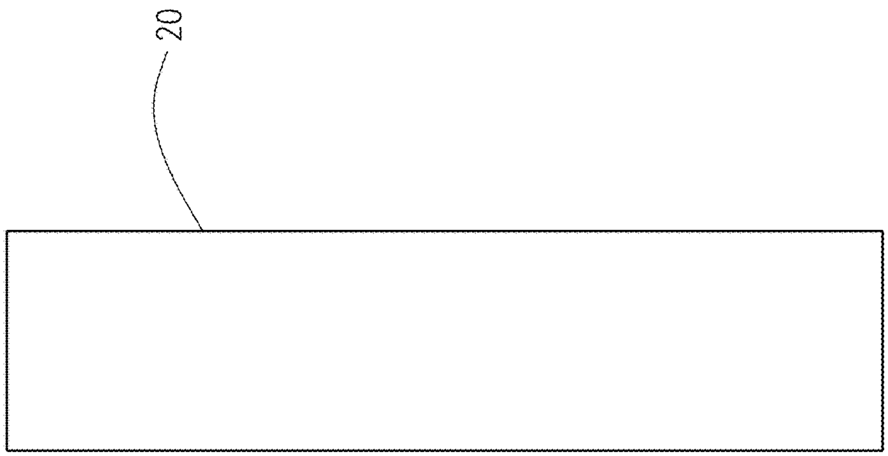



FIG. 2B

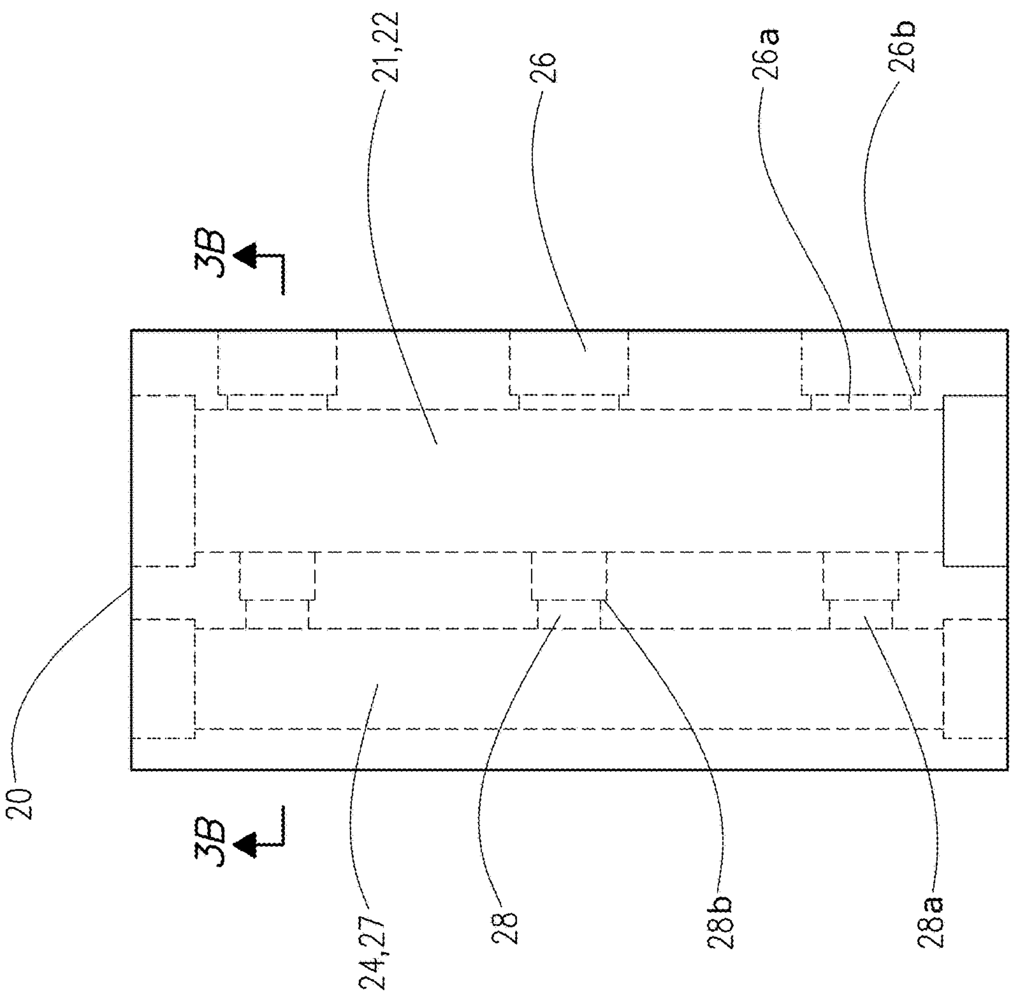



FIG. 2A

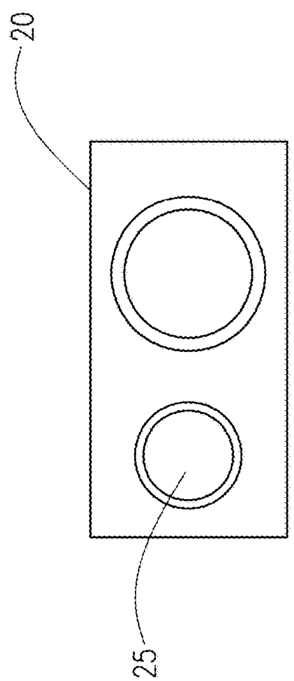



FIG. 2D

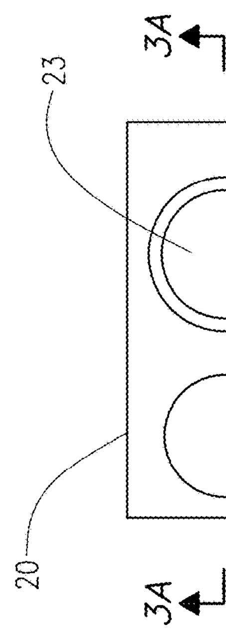



FIG. 2E

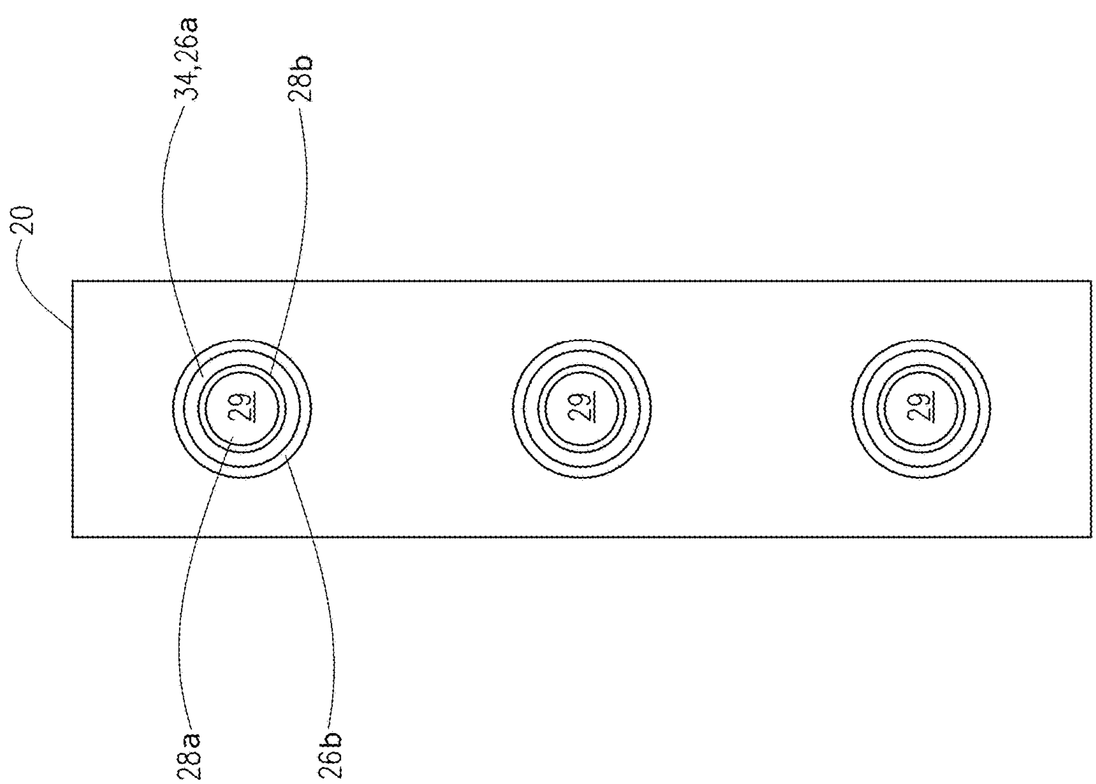



FIG. 2C

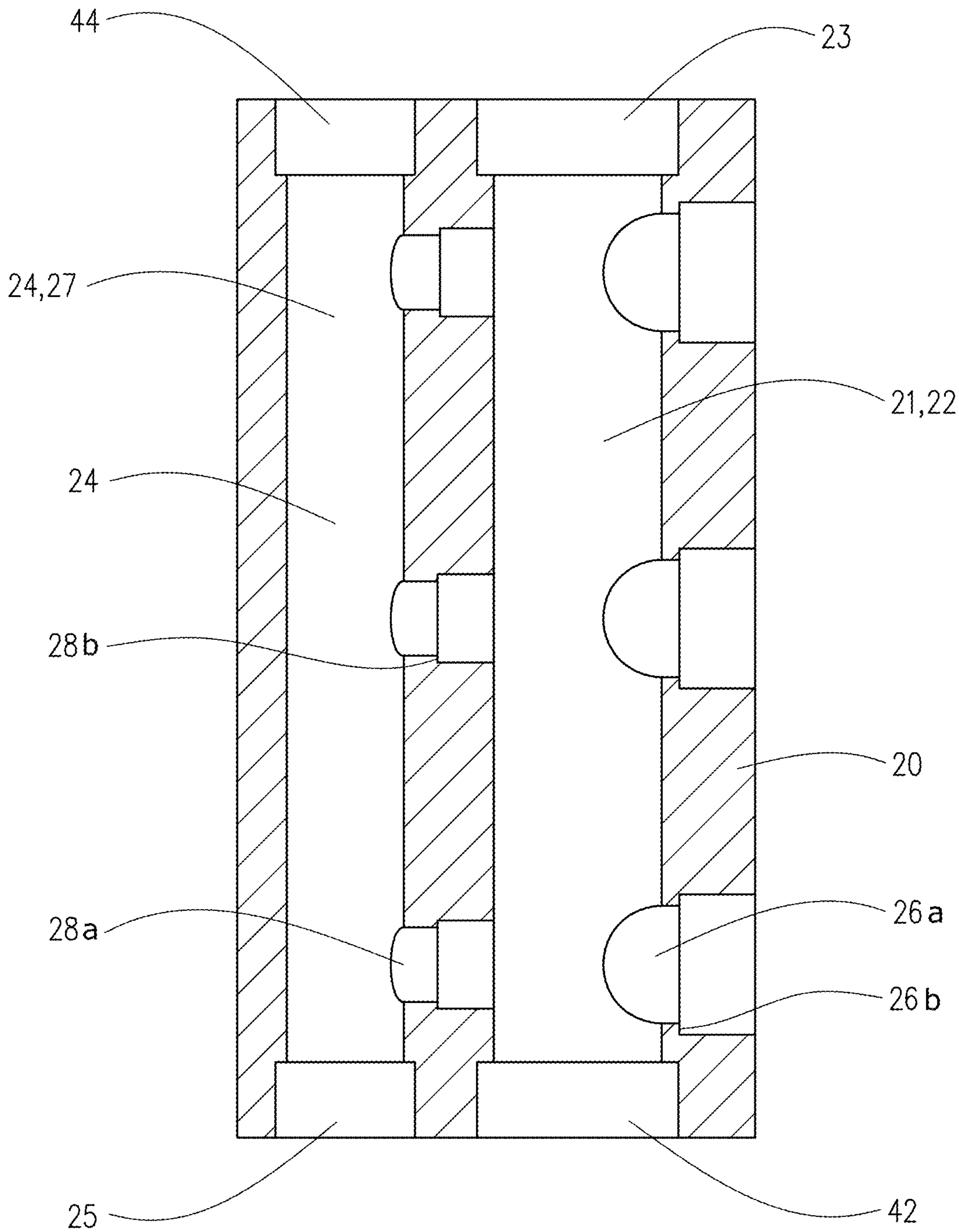



FIG. 3A

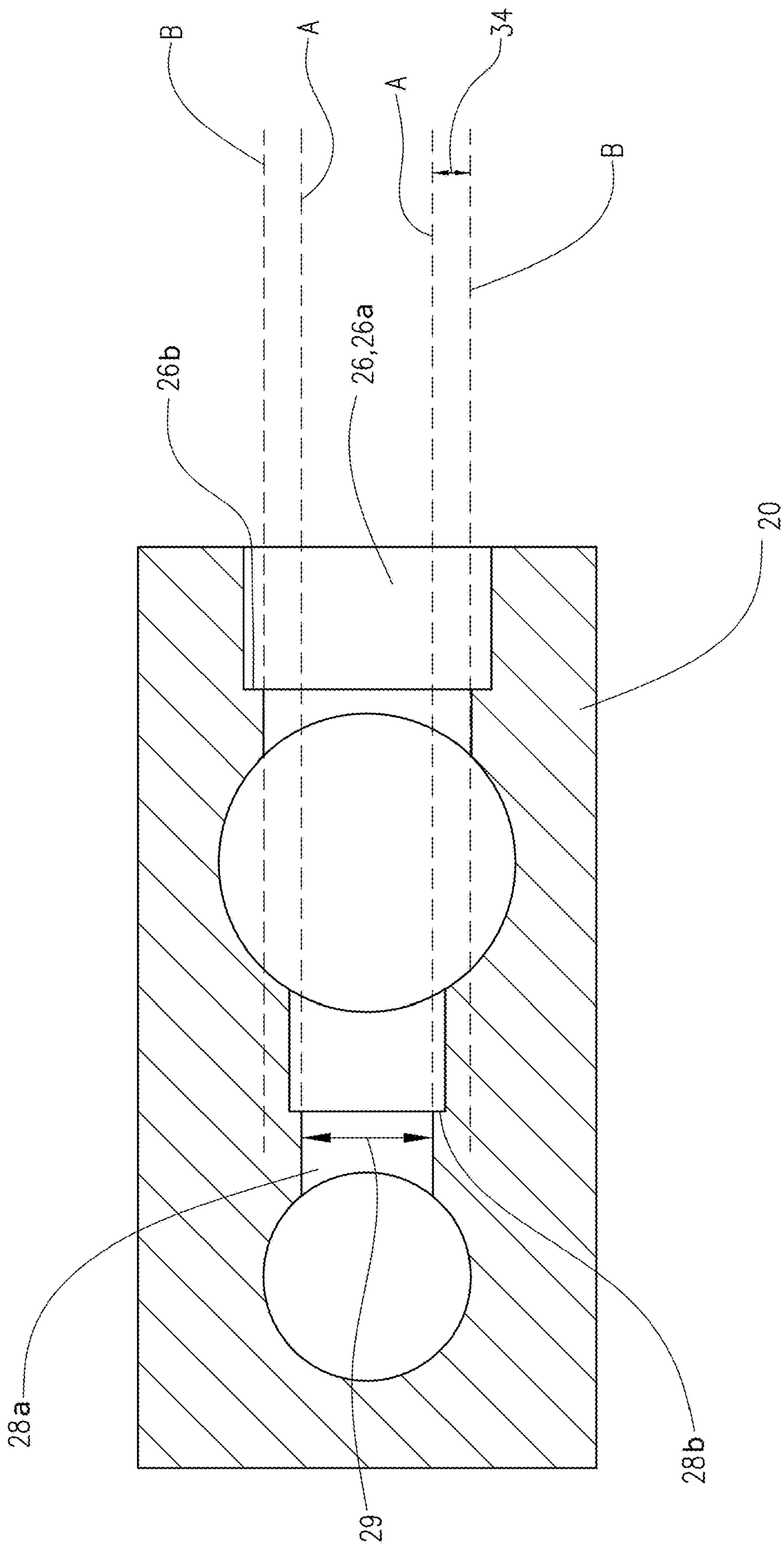



FIG. 3B

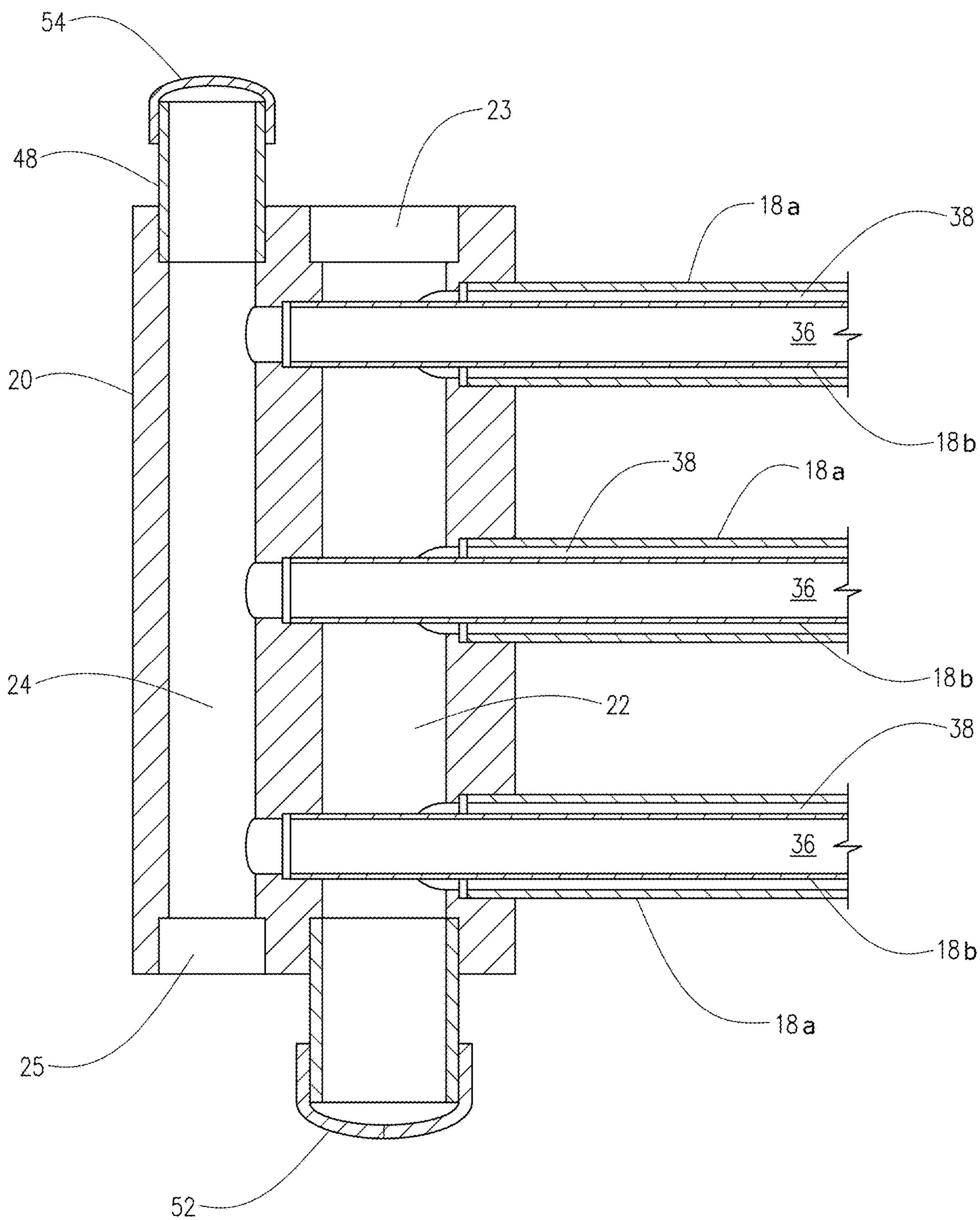



FIG. 4A

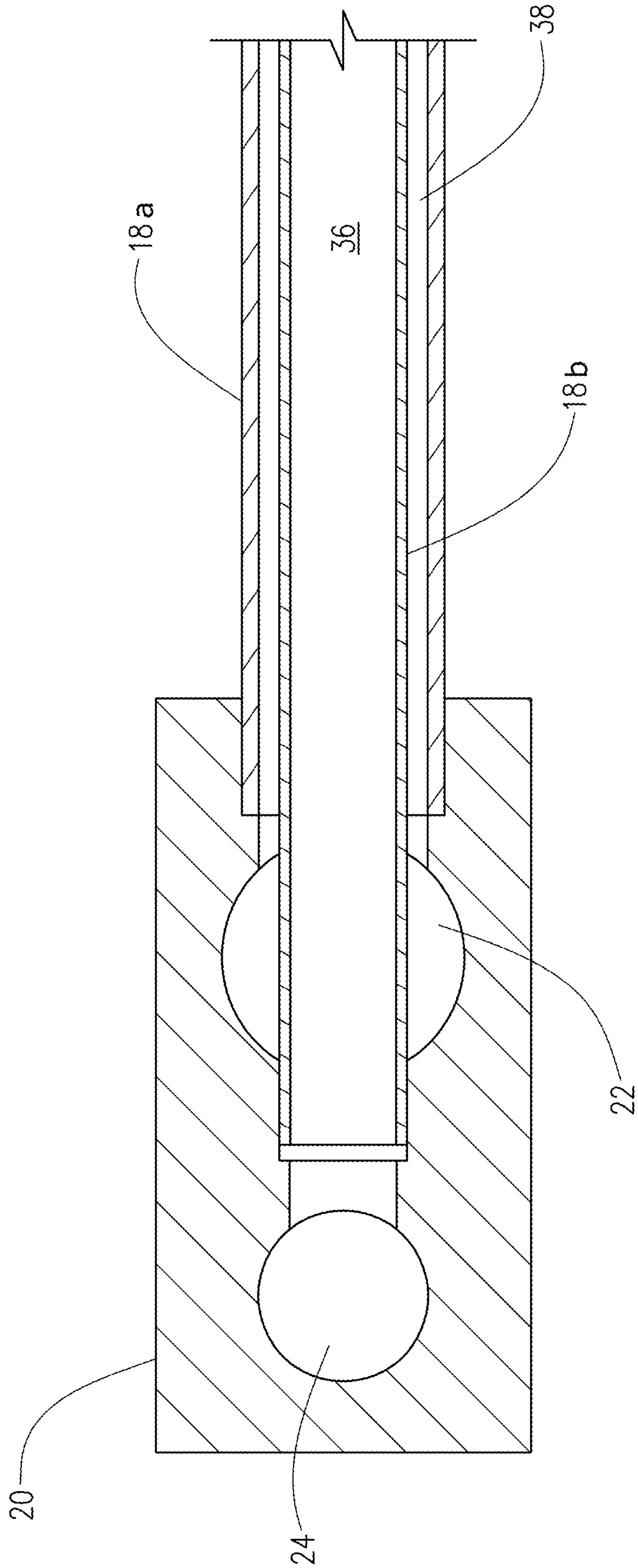



FIG. 4B

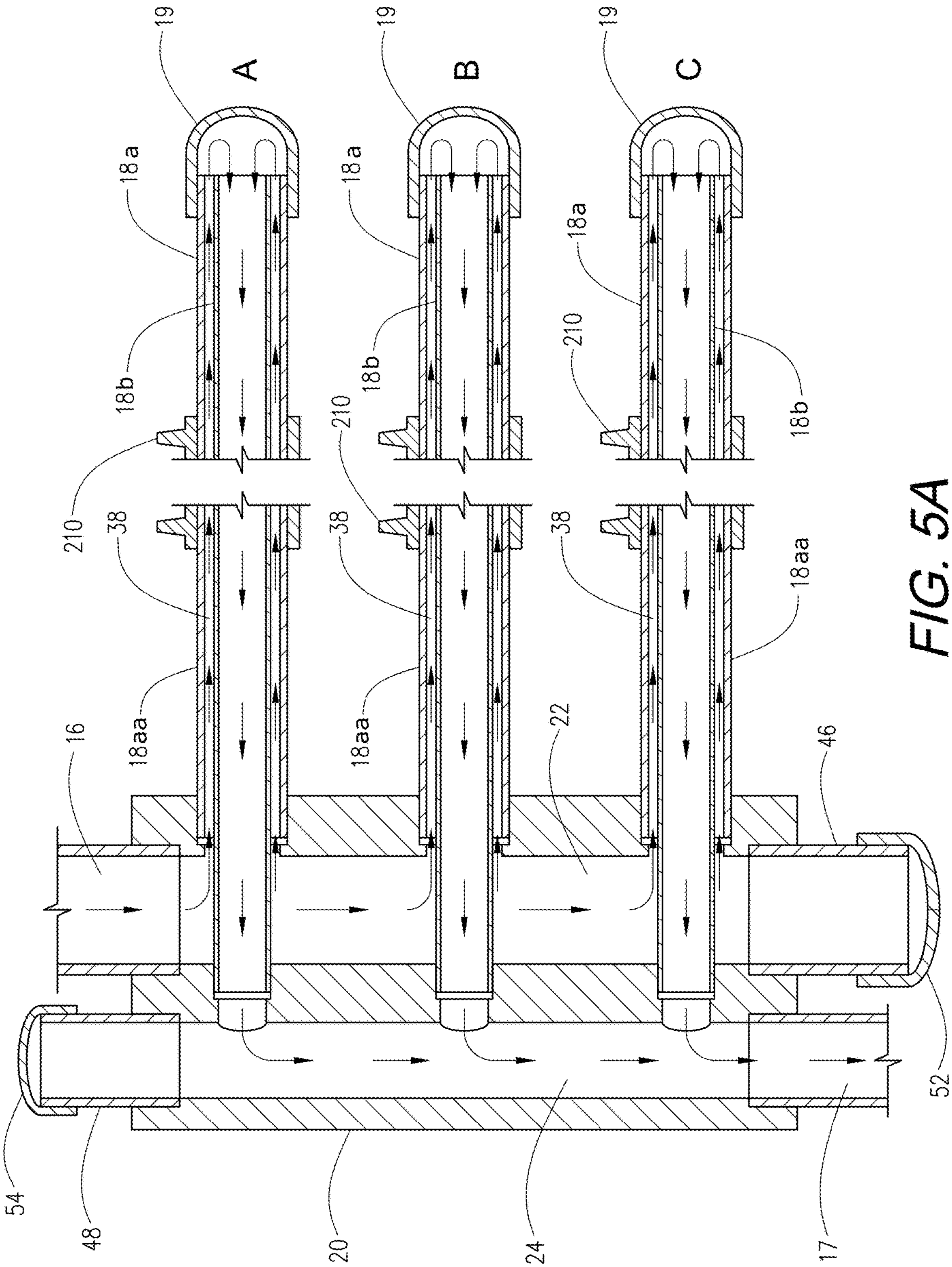



FIG. 5A

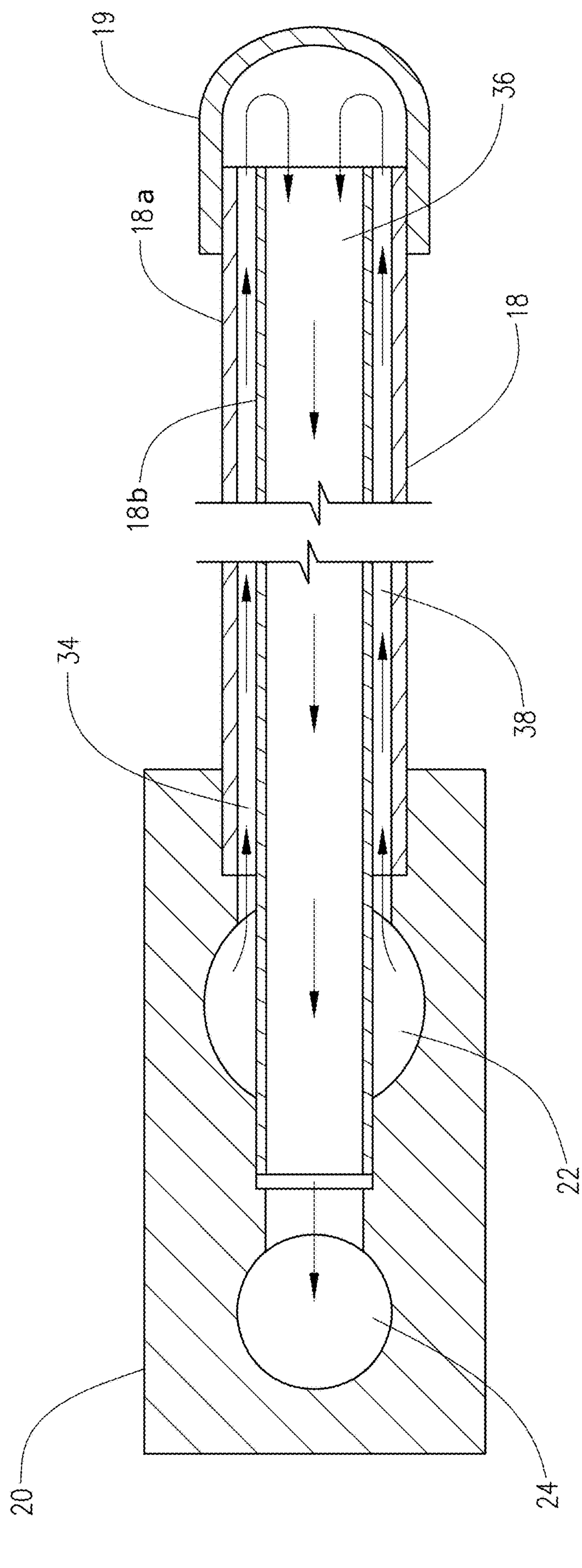



FIG. 5B

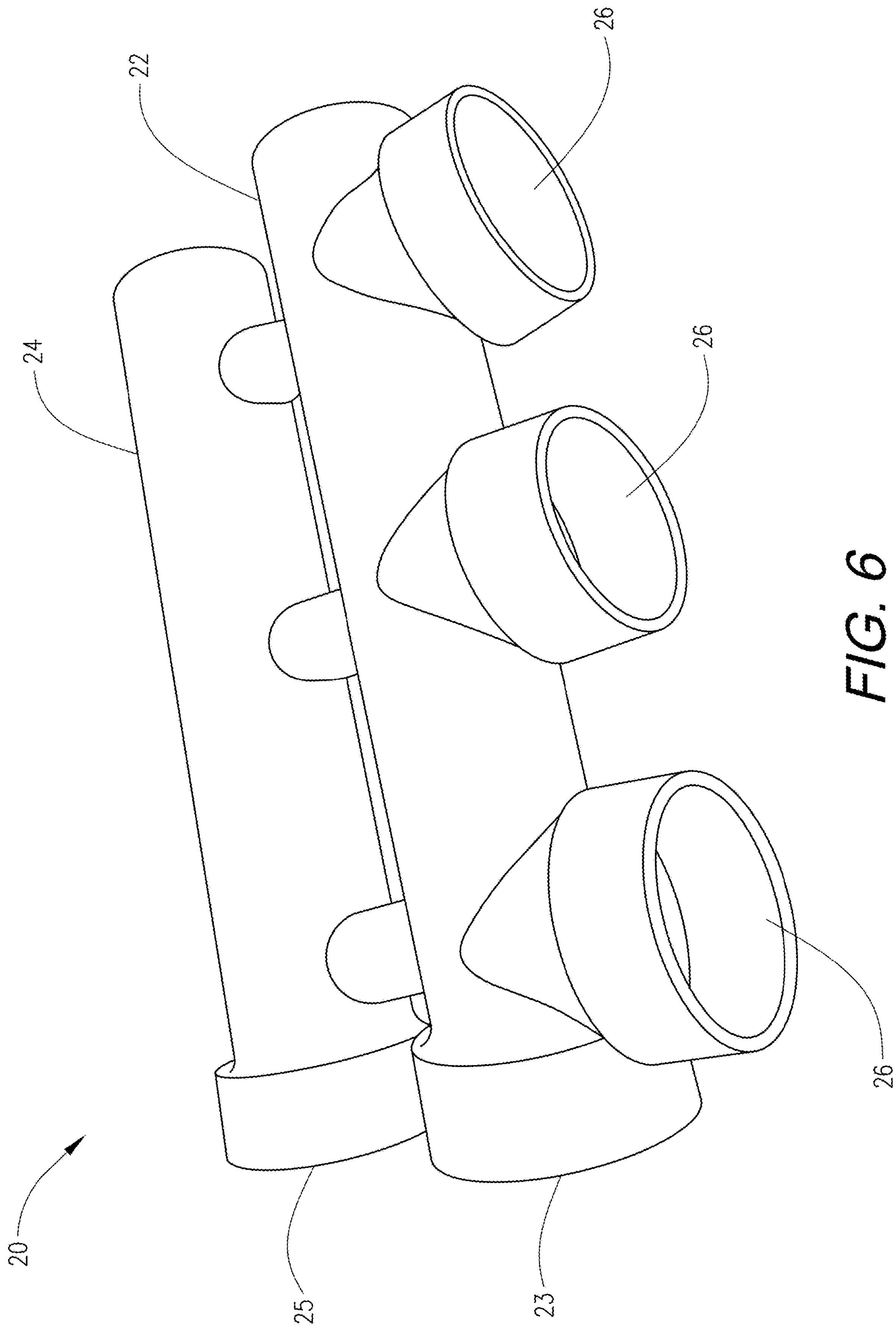



FIG. 6

| PRESSURE TAP LOCATIONS | PSID |
|---|---|
| A2 - A1 | 0.25 |
| B2 - B1 | 0.44 |
| C2 - C1 | 0.33 |

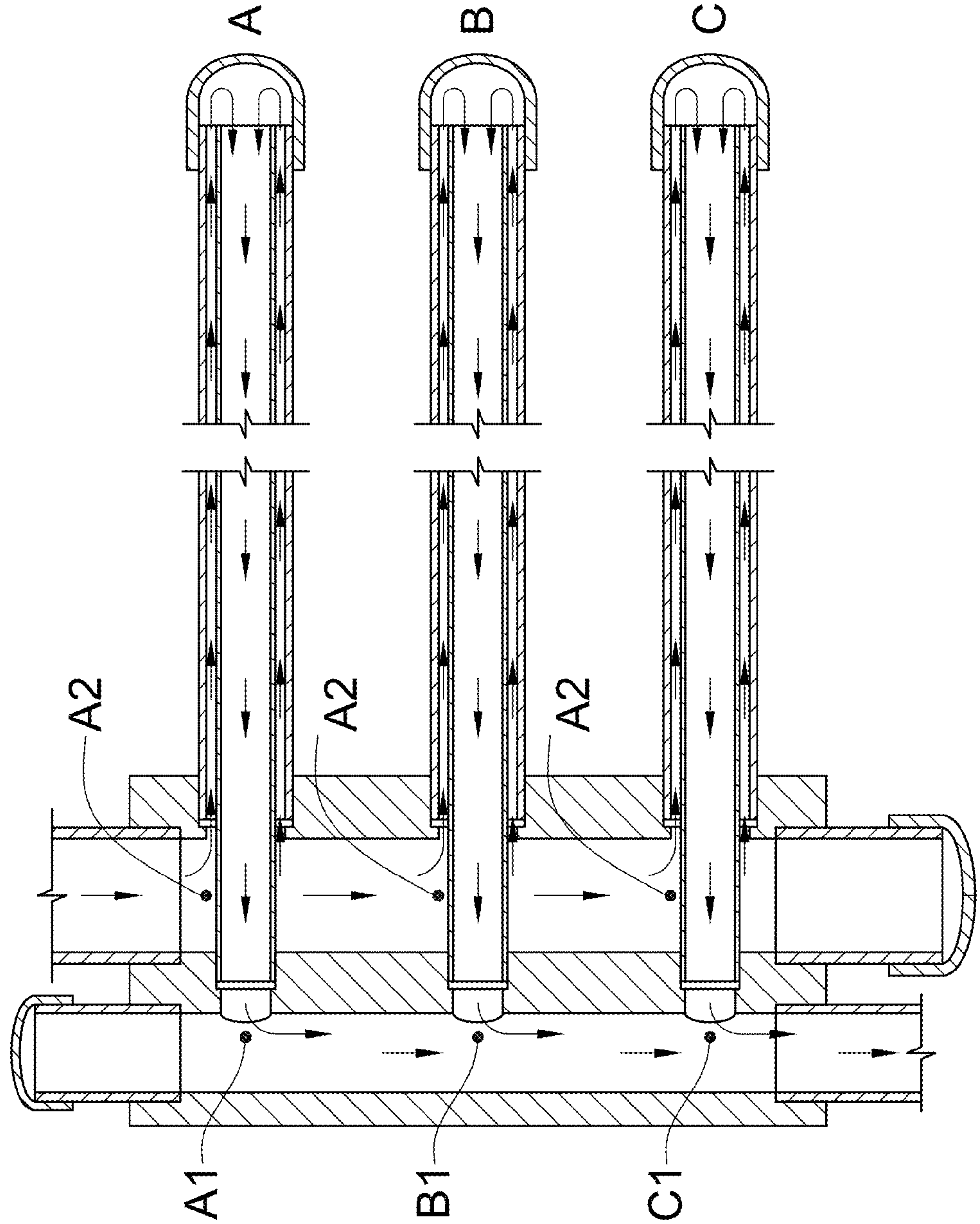



FIG. 7

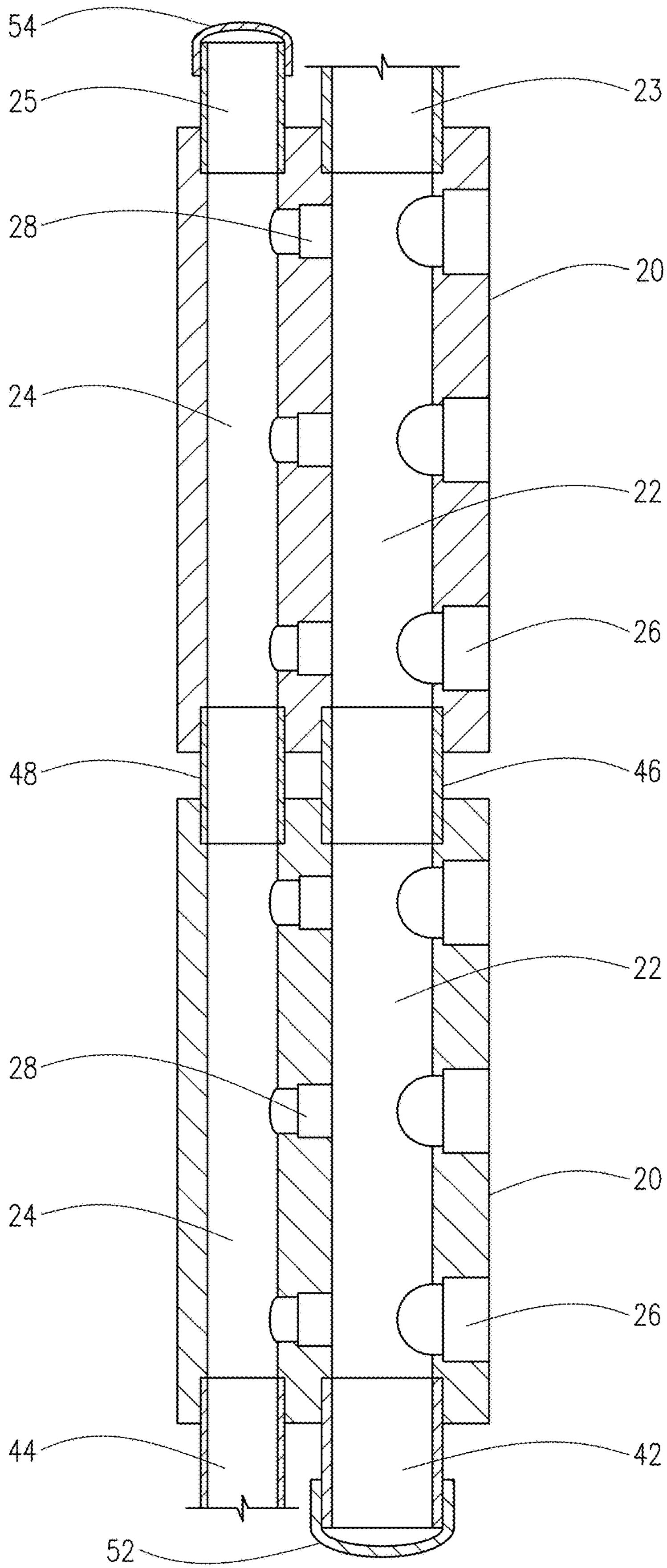



FIG. 8

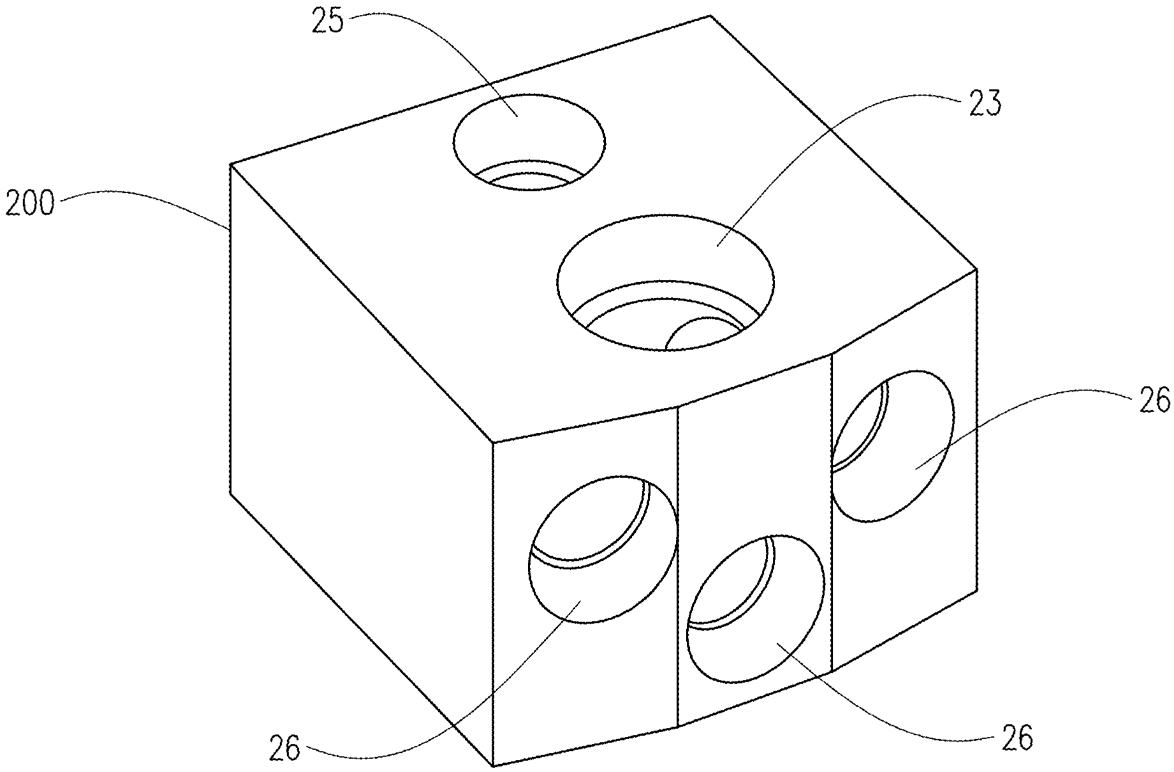



FIG. 9A

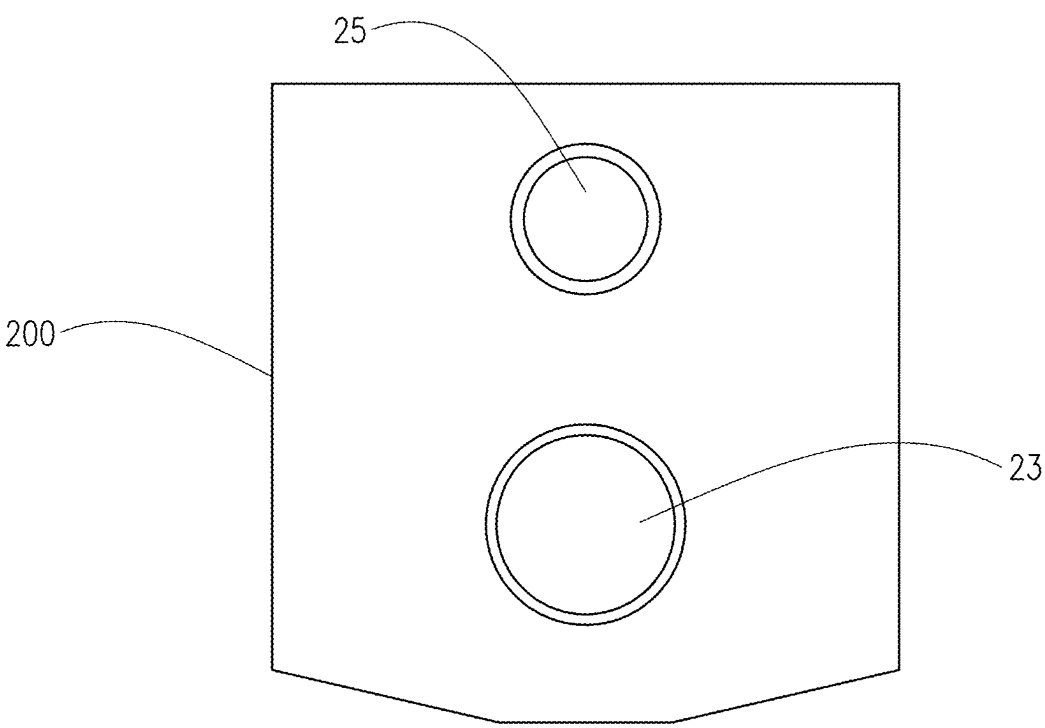



FIG. 9B

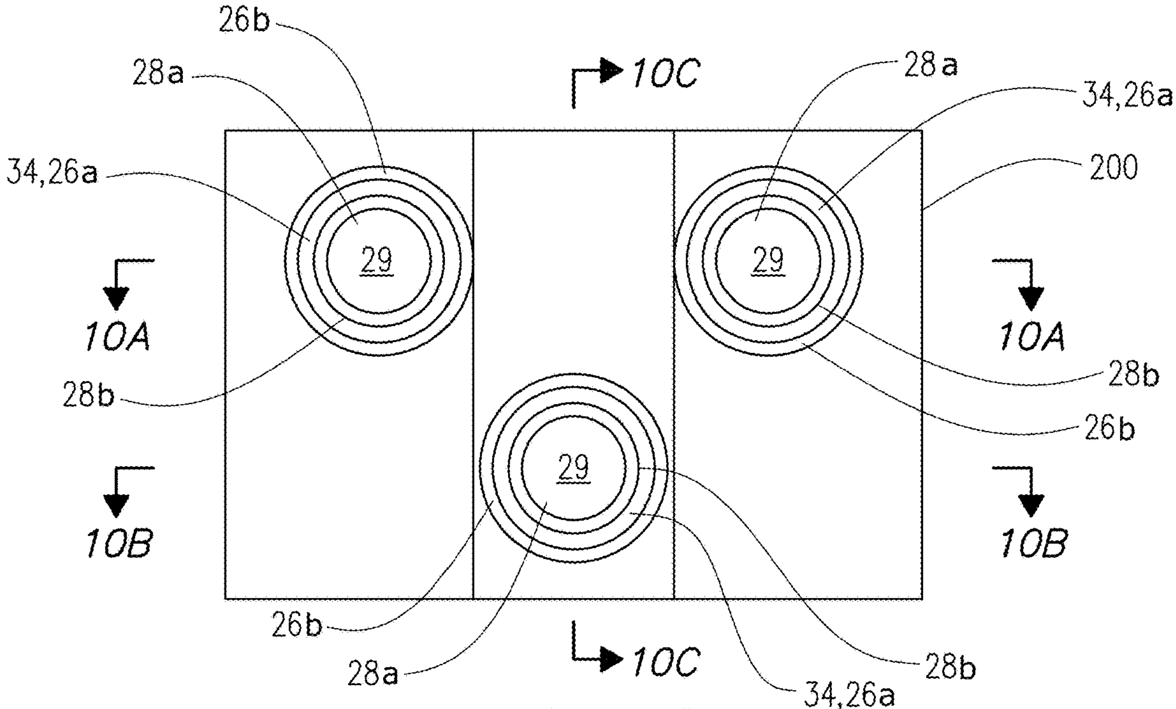



FIG. 9C

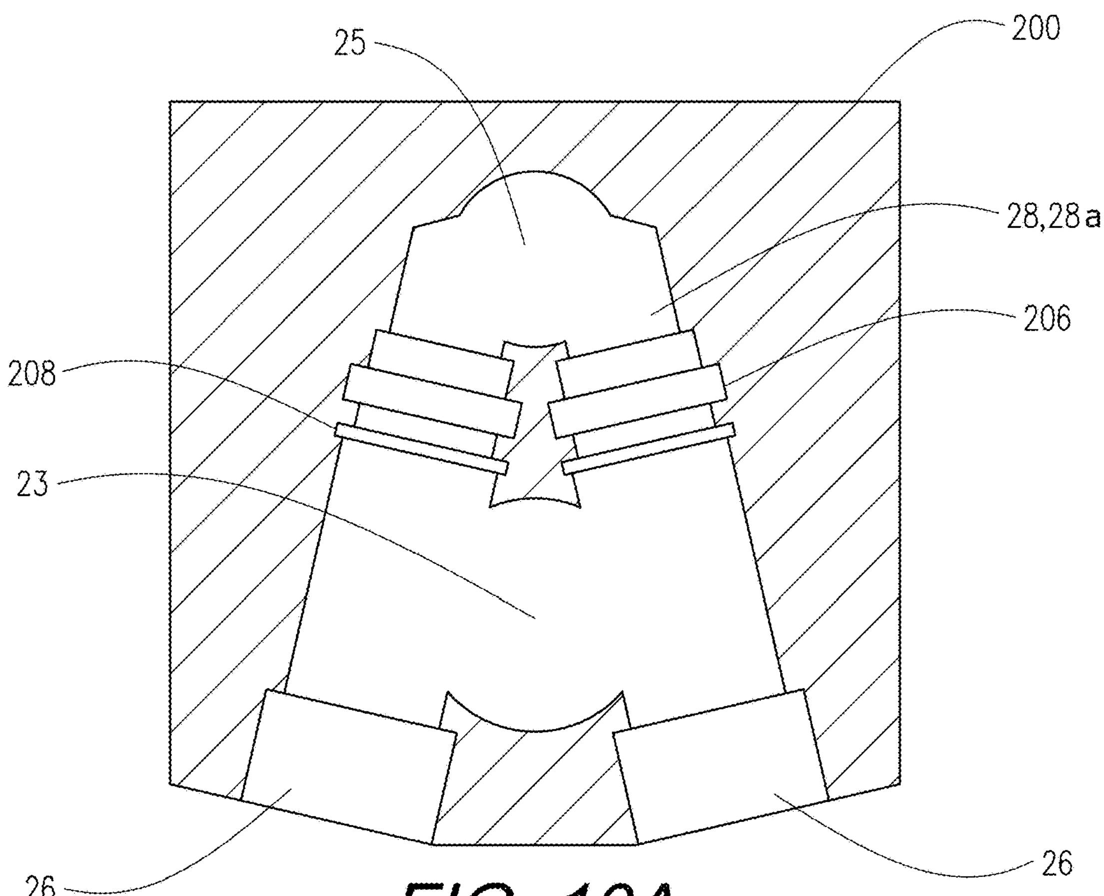



FIG. 10A

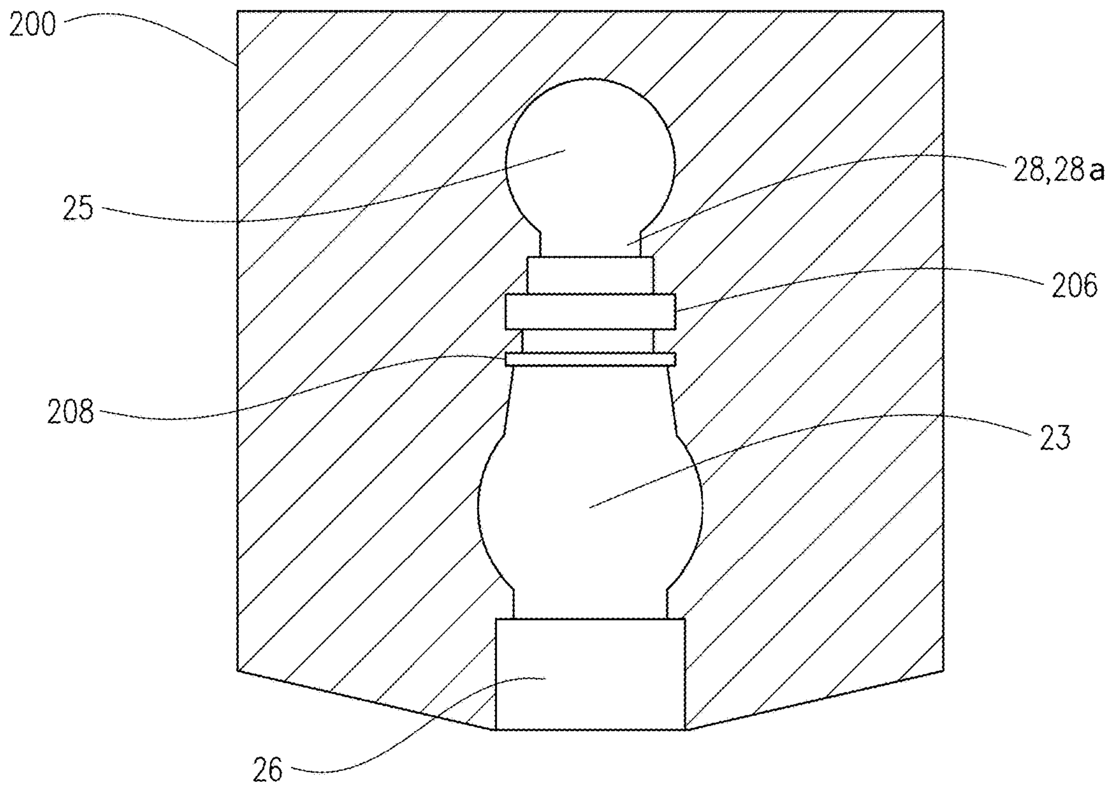



FIG. 10B

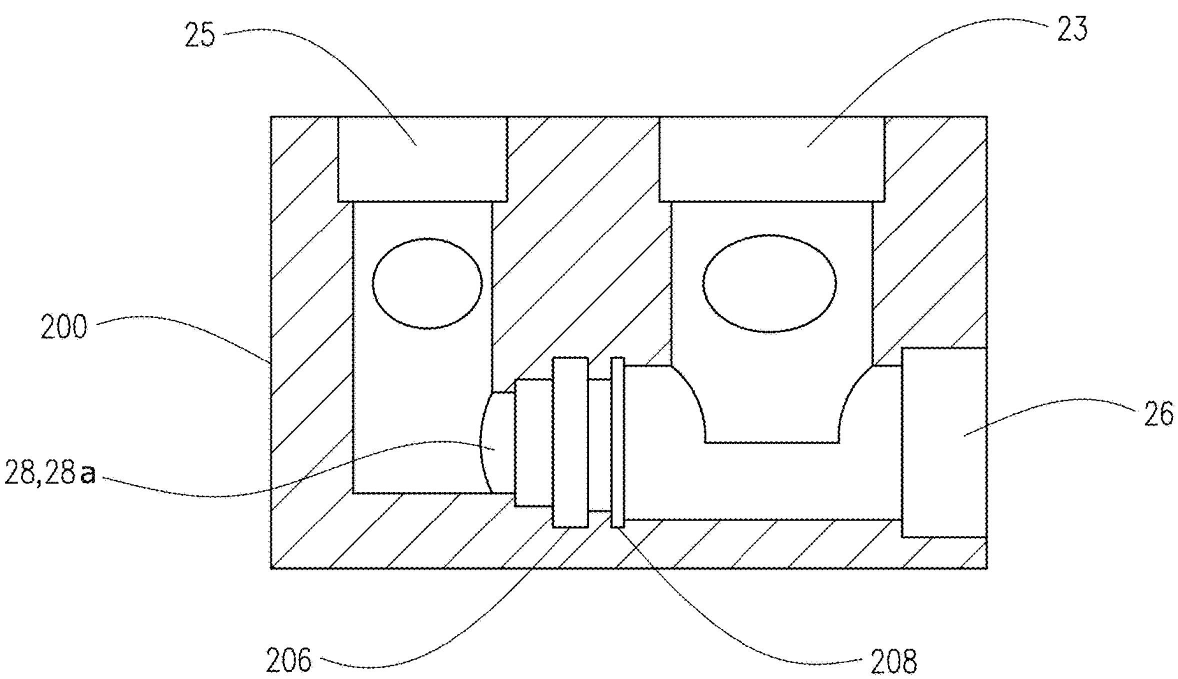



FIG. 10C

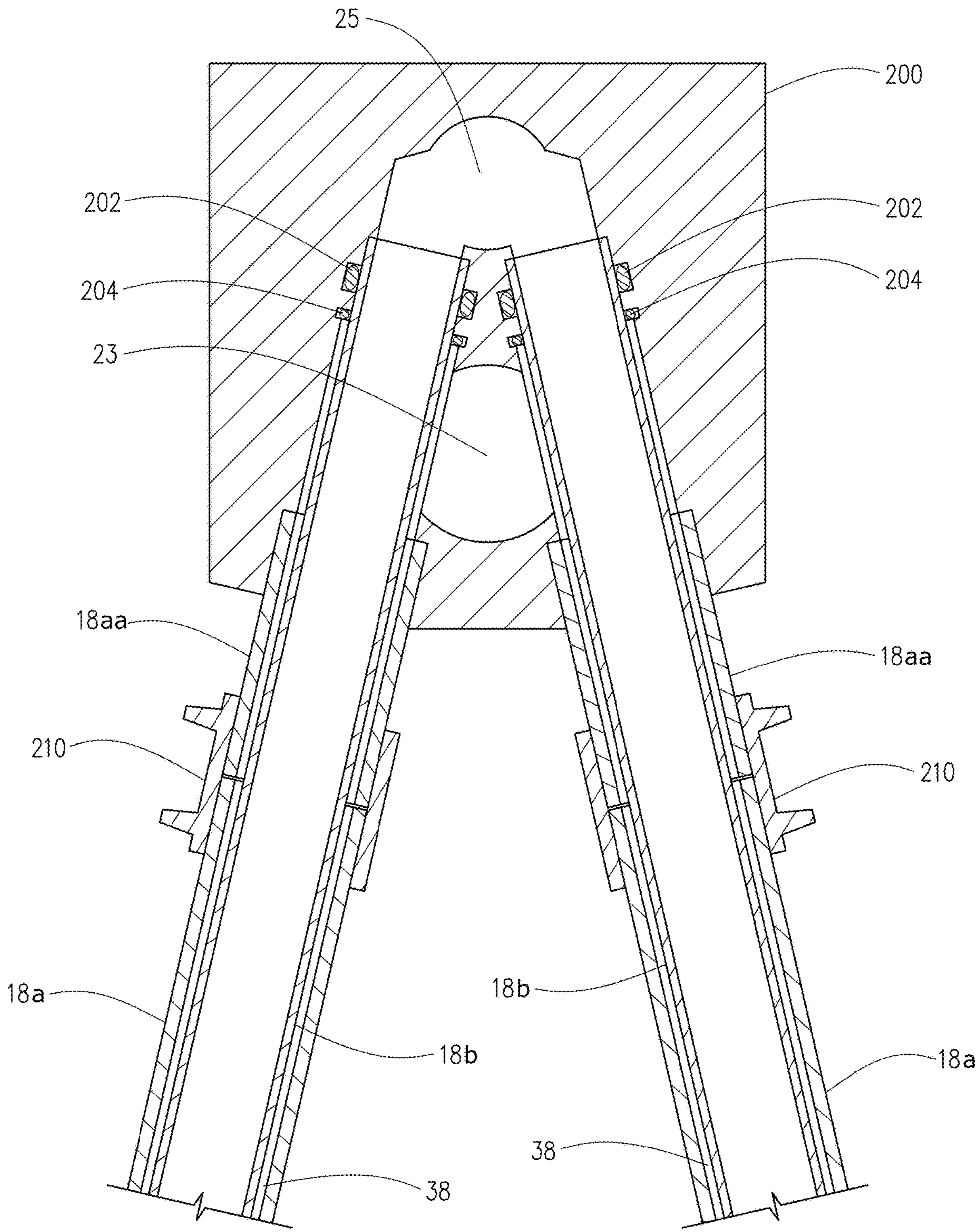



FIG. 11A

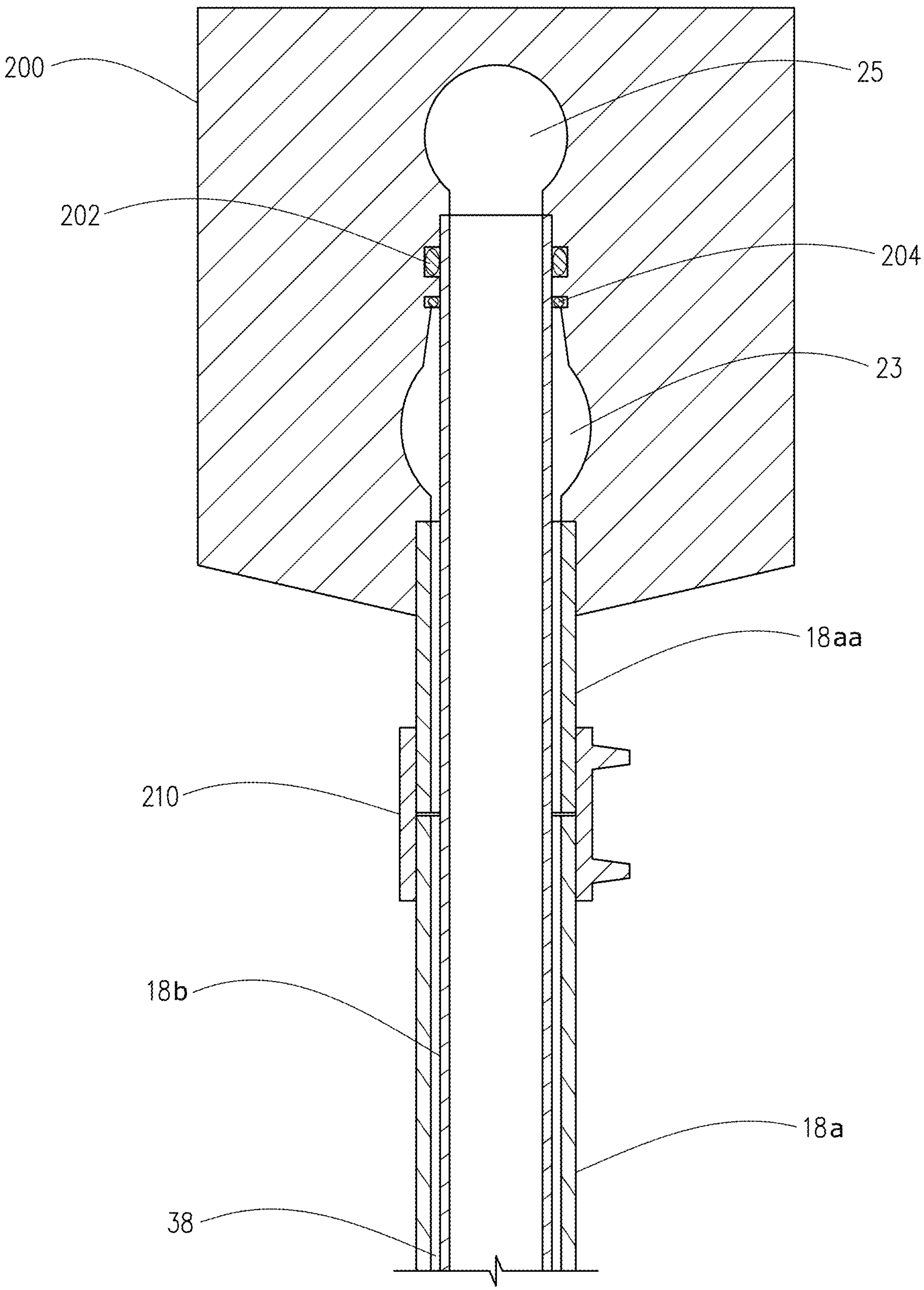



FIG. 11B

# INTEGRATED SUPPLY AND RETURN MANIFOLD FOR TUBE-IN-TUBE HEAT TRANSFER

## CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Provisional Application No. 63/556,117 filed on Feb. 21, 2024, and to U.S. Provisional Application No. 63/556,729 filed on Feb. 22, 2024, each of which are incorporated herein.

## STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] This invention was made with government support under grant numbers 2020-33610-32389 and 2022-33610-37902 awarded by US Department of Agriculture's National Institute of Food and Agriculture division. The government has certain rights in the invention.

## BACKGROUND

[0003] Manifolds are commonly used in fluid flow systems. One problem with currently available manifolds is the inability to provide balanced flow throughout the associated system. Another problem with currently available manifolds relates to the size requirements. Therefore, the industry would benefit from a manifold having reduced size which also provides balanced flow throughout the associated system.

## SUMMARY

[0004] In one aspect, the present disclosure provides an integrated manifold for use in a heat exchange system. The integrated manifold comprises a distribution plenum having a first primary inlet and at least one distribution plenum fluid outlet port. Additionally, the integrated manifold includes a collection plenum having a first primary outlet and at least one collection plenum fluid inlet port. The distribution plenum and collection plenum are integrally formed with one another such that that at least one distribution plenum outlet and at least one collection plenum inlet share the same central axis.

[0005] In another aspect, the present disclosure provides a method of operating a closed loop heat exchange system. According to the disclosed method, an integrated manifold having a distribution plenum and a collection plenum within a single manifold is provided. The integrated manifold is incorporated into a closed loop tube-within-tube heat exchange loop. The configuration of the integrated manifold in cooperation with the operation of the closed loop heat exchange system's pump(s) provides enhanced heat exchange by ensuring turbulent flow through the closed loop heat exchange loop.

[0006] Another embodiment provides a manifold and heat exchange pipes for a balanced flow heat exchange system. The manifold and heat exchange pipes for a balanced flow heat exchange system includes a distribution plenum having a first primary inlet and at least one distribution plenum fluid outlet port. The system also includes a collection plenum having a first primary outlet and at least one collection plenum fluid inlet port. The distribution plenum and the collection plenum are integrated with one another such that the at least one distribution plenum fluid outlet port and the at least one collection plenum fluid inlet port share the same central axis. Additionally, a first heat exchange pipe is positioned within the at least one distribution plenum fluid outlet port, the first heat exchange pipe having a first interior surface, a first exterior surface, a first inside diameter and a first thickness. Additionally, a second heat exchange pipe is positioned within the at least one collection plenum fluid inlet port, the second heat exchange pipe having a second interior surface, a second exterior surface, a second inside diameter, an interior cross-sectional area and a second thickness. Thus, the second heat exchange pipe passes through the first heat exchange pipe such that the first interior surface of the first heat exchange pipe and the second exterior surface of the second heat exchange pipe define an annulus. Accordingly, the annulus has a cross-sectional area which is about equal to a cross-sectional area of the interior cross-sectional area of the second heat exchange pipe. Optionally, the cross-sectional area of the interior cross-sectional area of the second heat exchange pipe no more than about 3% less than the cross-sectional area of the annulus.

[0007] In yet another embodiment, the present disclosure provides an integrated manifold for use in a heat exchange system. The integrated manifold comprises a distribution plenum having a first primary inlet and at least one distribution plenum fluid outlet port. Additionally, the integrated manifold includes a collection plenum having a first primary outlet and at least one collection plenum fluid inlet port. The distribution plenum and collection plenum are integrally formed with one another such that that at least one distribution plenum outlet and at least one collection plenum inlet share the same central axis. Also provided with the integrated manifold is a first stub pipe positioned within the at least one distribution plenum fluid outlet port, the first stub pipe having a first interior surface, a first exterior surface, a first inside diameter and a first thickness

## BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** schematically represents a heat transfer system which incorporates the manifold of the present invention.

[0009] FIG. **2** provides top view FIG. **2**A, opposing side views FIGS. **2**B, **2**C, and opposing end views FIGS. **2**D, **2**E of the manifold.

[0010] FIGS. **3**A and **3**B are sectional views taken along lines A-A and B-B in FIGS. **2**E and **2**A respectively.

[0011] FIGS. **4**A and **4**B are sectional views taken along lines A-A and B-B in FIGS. **2**E and **2**A respectively with heat exchange loop pipes connected to the manifold.

[0012] FIGS. **5**A and **5**B depict the loop portion of the heat-exchange system extending from the manifold in the same planes as FIGS. **4**A and **4**B.

[0013] FIG. **6** is a perspective view of one example of the manifold.

[0014] FIG. **7** depicts the locations used to measure pressure differential across the manifold.

[0015] FIG. **8** depicts two manifolds joined in series.

[0016] FIG. **9**A is a perspective view of an alternative embodiment of the manifold wherein the inlet/outlet ports project at three different angles from the distribution and collection plenums.

[0017] FIG. **9**B is a top view of the embodiment of FIG. **9**A.

**[0018]** FIG. **9**C is a front view of the embodiment of FIG. **9**A.
**[0019]** FIG. **10**A is a sectional view taken along lines A-A of FIG. **9**C.
**[0020]** FIG. **10**B is a sectional view taken along lines B-B of FIG. **9**C.
**[0021]** FIG. **10**C is a sectional view taken along lines C-C of FIG. **9**C.
**[0022]** FIG. **11**A is a sectional view taken along lines A-A of FIG. **9**C with heat-exchange pipes installed.
**[0023]** FIG. **11**B is a sectional view taken along lines B-B of FIG. **9**C with heat-exchange pipes installed.

## DETAILED DESCRIPTION

**[0024]** The drawings included with this application illustrate certain aspects of the embodiments described herein. However, the drawings should not be viewed as exclusive embodiments. The subject matter disclosed is capable of considerable modifications, alterations, combinations, and equivalents in form and function, as will occur to those skilled in the art with the benefit of this disclosure.

**[0025]** The present disclosure may be understood more readily by reference to these detailed descriptions. For simplicity and clarity of illustration, where appropriate, reference numerals may be repeated among the different figures to indicate corresponding or analogous elements. The following description is not to be considered as limiting the scope of the embodiments described herein. The drawings are not necessarily to scale and the proportions of certain parts may have been exaggerated to better illustrate details and features of the present disclosure. Also, the phraseology and terminology employed herein is for the purpose of description and should not be regarded as limiting except where indicated as such.

**[0026]** Throughout this disclosure, the terms “about”, “approximate”, “substantially” and variations thereof, are used to indicate that a value includes the inherent variation or error for the device, system, or measuring method being employed as recognized by those skilled in the art.

**[0027]** Although designed initially for use in the heat exchange systems, particularly for use in the geothermal environment, the manifold **20** of the present disclosure may also find use in other environments. With reference to FIG. **1**, manifold **20** is schematically depicted as part of a geothermal, closed-loop heat exchange system **10**. Closed loop heat exchange system **10** provides heating or cooling to building **12** through use of a heat pump **13**, fluid pump **14**, outflow and return lines **16**, **17** and a series of pipe within a pipe, heat exchange loops **18**.

**[0028]** With reference to FIGS. **2-5** and **7**, manifold **20** includes a distribution plenum **22** and a collection plenum **24**. Distribution plenum **22** has a primary inlet port **23** in fluid communication with heat pump **13** and fluid pump **14** via outflow line **16**. Fluid pump **14** provides motive force to liquid passing through heat exchange system **10**. Distribution plenum **22** receives fluid from outflow line **16** at primary inlet port **23** and provides for even distribution of the fluid to heat exchange loops **18** via central passageway **21** and at least one and more typically multiple distribution plenum fluid outlet ports **26**. Collection plenum **24** has at least one and typically multiple collection plenum fluid inlet ports **28** which provide fluid flow to central passageway **27** of collection plenum **24** from heat exchange loops **18**. Collection plenum **24** returns fluid to fluid pump **14** through primary outlet port **25**. In the following detailed discussion describing the components depicted in the FIGS., distribution plenum fluid outlet ports **26** are also referred to as outlet ports **26*a*** and collection plenum fluid inlet ports **28** are also referred to as inlet ports **28*a***. Outlet ports **26*a*** and inlet ports **28*a*** do not include the area represented by offsets **26*b***, **28*b***.

**[0029]** As depicted in FIGS. **2-5** and **7**, corresponding outlet ports **26** and inlet ports **28** share a common central axis. The configuration of outlet ports **26** and inlet ports **28** provide a key aspect to the present invention. Specifically, the cross-sectional area of an outlet port **26** is two times the cross-sectional area of the corresponding inlet port **28**. As used herein, the referenced cross-sectional areas of ports **26**, **28** do not include any offsets **26*b***, **28*b*** provided for accommodating the thickness of heat exchange pipes **18*a***. **18*b***. As such, offsets **26*b*** and **28*b*** are outside of the fluid flow paths defined by ports **26** and **28**. Rather, **26*a*** and **28*a*** define the fluid flow paths out of distribution plenum **22** and into collection plenum **24**. Thus, when using manifold **20** or **200** with heat exchange pipes **18*a***, **18*b*** in place, fluid flow through outlet port **26** equals fluid flow through inlet port **28**. In this manner manifolds **20** and **200** provide balanced fluid flow through closed-loop heat exchange system **10**, thereby reducing the load on fluid pump **14** while reducing the footprint of manifolds **20** and **200**. To help visualize the fluid flow paths relative to ports **26** and **28** dashed lines A and B have been added to FIG. **3**B. The gap between the upper A and B lines and the gap between the lower A and B lines corresponds to annulus **34**.

**[0030]** As depicted in FIGS. **2**, **3**A and **3**B, ports **26** and **28** are configured to receive heat-exchange pipes **18*a*** and **18*b*** respectively. As reflected in FIGS. **2**A and **3**A, prior to attachment of heat exchange pipes **18*a*** and **18*b***, fluid inlet ports **28** intersect the central passageway **21** of distribution plenum **22**. In one embodiment, to provide for a continuous flow path and to accommodate the thickness of the walls of heat-exchange pipes **18*a***, **18*b***, each outlet port **26** has an offset **26*b*** of larger diameter than the passageway **26*a*** into distribution plenum **22**. Likewise, each inlet port **28** has an offset **28*b*** of larger diameter than the passageway **28*a*** into collection plenum **24**. The width of offsets **26*b*** and **28*b*** generally correspond to the thickness of heat-exchange pipes **18** and provides for a match of the interior of the pipe to the respective ports, thereby providing a continuous velocity flow of fluids to/from pipes **18*a*/18*b*** into and from manifold **22**. Further, collection plenum **24** has a primary outlet port **25** in fluid communication with fluid pump **14** and heat pump **13** via return line **17**. Thus, the current embodiment permits a leakproof connection, i.e. water tight connection between ports **26**, **28** and heat-exchange pipes **18*a***, **18*b***. When using plastic pipe, one suitable connection technique is a heat fusion weld. The use of the configuration with offset regions **26*b*** and **28*b*** is optional and may be omitted or modified if a different type of heat-exchange pipe **18*a***, **18*b*** and/or connection method is used. While the present disclosure uses the term “port,” those in the industry may also use the term socket for the same connection point or element.

**[0031]** With reference to FIGS. **4**A-**5**B, each exterior pipe **18*a*** of each heat exchange loop **18** is in fluid communication with a corresponding outlet port **26** of distribution plenum **22**. Likewise, each interior pipe **18*b*** of each heat exchange loop **18** is in fluid communication with a corresponding inlet port **28** of collection plenum **24**. With ports **26**, **28** aligned on a common central axis, an extension of the lines corresponding to the configuration of ports **26** and **28** defines a first annulus **34**. See FIG. **3**B. In this embodiment, the cross-sectional area of annulus **34** is defined by the diameter of inlet port passageway **28** and the diameter of outlet port passageway **26**. With heat-exchange pipes **18***a*, **18***b* installed in ports **26**, **28**, a continuous annulus **38** is formed extending from ports **26**, **28** through and including heat-exchange pipes **18***a*, **18***b*. Annulus **38** has the same cross-sectional area as annulus **34**. As depicted in FIGS. **5**A and **5**B, the terminal ends of heat exchange pipes **18***a*, **18***b* are covered by cap **19**. Thus, flow from each heat exchange loop exterior pipe **18***a* transitions to interior pipe **18***b* at a cap **19**.

**[0032]** Manifold **20** has a configuration which provides for even distribution of fluid flow between multiple outlet ports **26** with a corresponding collection and combination of returning fluid through multiple inlet ports **28**. The relative configuration of outlet ports **26** and inlet ports **28** enhances turbulent fluid flow through pipes **18** by providing corresponding cross-sectional areas for fluid flow. Specifically, the cross-sectional area of annulus **34** is substantially equal to the cross-sectional area **29** defined by inlet port **28***a*. Thus, with pipes **18***a* and **18***b* installed, the cross-sectional area **36** of the interior of heat-exchange pipe **18***b* also equals the cross-sectional area **29** of inlet port **28***a*. As a result of the configuration of pipes **18***a* and **18***b* an annulus **38** is defined. Cross-sectional area **29** of inlet port **28***a* which corresponds to cross-sectional area **36** of the interior of heat-exchange pipe **18***b* should never be larger than the area defined by either annulus **34** or **38**. In general, cross-sectional area **29** of inlet port **28***a* may be less than or equal to the cross-sectional area of annulus **34** and annulus **38**. More typically, cross-sectional area **29** of inlet port **28***a* will be about equal to or no more than about 3% less than the cross-sectional area of either annulus **34** or **38**. In most instances, the cross-sectional area of each annulus **34**, **38** will approximately equal the cross-sectional area **29** of inlet port **28***a*. Thus, manifold **20** enables a balanced flow through distribution plenum **22** and collection plenum **24**. Likewise, the cross-sectional area and volume of each pair of exterior and interior heat exchange pipes **18***a*, **18***b* is about the same. The volume defined by caps **19** defines a transition area from outflow to return flow. This volume does not negatively impact flow through closed loop heat exchange system **10** or manifold **20**.

**[0033]** As a result of the configurations of manifold **20** and closed loop heat exchange system **10**, each heat-exchange loop **18** will operate with similar pressure difference between distribution plenum **22** and collection plenum **24**. See the PSID data provided with FIG. **7**. Further, as demonstrated by Table 1 below, pressure differences between points within distribution plenum **22** will also be minimal as will the pressure differences between points within collection plenum **24**. Hence, flow rates through outflow and return lines **16**, **17** will be substantially similar. In most cases, the flow rates differences through outflow and return lines **16**, **17** will be insignificant.

**[0034]** To enhance heat exchange between the ground in which closed-loop heat exchange system **10** is installed and exterior pipe **18***a*, the flow rate through annulus **38** between pipes **18***a*, **18***b* should be sufficient to substantially preclude laminar flow. Thus, the flow rate should induce turbulent flow in this region in order to improve heat exchange between the ground and pipe **18***a*. Likewise, the flow rate through the interior of pipe **18***b* should also maintain turbulent, non-laminar flow in order to improve heat exchange between the fluid passing through inner pipe **18***b* and outer pipe **18***a*. Additionally, the configuration of outlet ports **26** and inlet ports **28** further enhance the ability of manifold **20** to provide turbulent fluid flow to heat exchange loops **18**.

**[0035]** With reference to FIG. **7**, differential pressure (PSID) was measured at each loop A, B and C across points A**1**-A**2**, B**1**-B**2** and C**1**-C**2** and within each plenum **22**, **24**. With reference to Table 1 below, the differential pressure for each heat-exchange loop A, B, and C is similar, which demonstrates that the flow through each loop will be approximately the same. Thus, the configurations of plenums **22** and **24** provide for balanced flow across manifold **20** and closed-loop heat exchange system **10**. Additionally, Table 1 reports pressure values for distribution plenum **22** and collection plenum **24** as taken at points A**1**, B**1**, C**1**, A**2**, B**2** and C**2**. The differential pressure data measurements between measurement points A**2**, B**2** and C**2** in distribution plenum **22** are insignificant as are the differential pressure measurements between points A**1**, B**1** and C**1** in collection plenum **24**. Therefore, the fluid volume passing through each of the heat exchange loops **18** will be approximately the same.

TABLE 1

| MEASUREMENT ACROSS LOOP OR PLENUM? | PRESSURE COMPARISON (UPSTREAM MINUS DOWNSTREAM) | PSID |
|---|---|---|
| LOOP | A2 − A1 | 0.25 |
| LOOP | B2 − B1 | 0.44 |
| LOOP | C2 − C1 | 0.33 |
| DISTRIBUTION PLENUM | A2 − B2 | −0.07 |
| DISTRIBUTION PLENUM | A2 − C2 | −0.04 |
| DISTRIBUTION PLENUM | B2 − C2 | 0 |
| COLLECTION PLENUM | A1 − B1 | 0.07 |
| COLLECTION PLENUM | A1 − C1 | 0 |
| COLLECTION PLENUM | B1 − C1 | −0.04 |

**[0036]** With continued reference to FIGS. **1**, **3**A, **4**A, **7**, **11**A and **11**B the flow path of fluid through Closed-loop Heat Exchange System **10** under typical operation will be described. Fluid pump **14** provides the motive force to transfer fluid through heat exchange loops **18** of Closed-loop Heat Exchange System **10**. As depicted, fluid flows from fluid pump **14** through outflow line **16** to manifold **20**. At manifold **20**, fluid passes through primary inlet port **23** and enters distribution plenum **22**. Subsequently fluid passes through ports **26** into annulus **34** and enters annulus **38** defined by pipes **18***a* and **18***b*. Upon reaching the end of the outermost point of heat exchange loop **18**, cap **19** directs fluid into the interior of pipe **18***b*. Pipe **18***b* carries the fluid to inlet ports **28** found in collection plenum **24**. From collection plenum **24**, the fluid returns to fluid pump **14** via return line **17** and then flows on to heat pump **13** completing one circuit of Closed-loop Heat Exchange System **10**. Additionally, the system may be operated with reverse flow with the same fluid connections.

**[0037]** Manifold **20** eliminates the need for separate supply and return manifolds thereby simplifying the installation, maintenance and operation of closed loop heat exchange system **10**. As a result, the overall costs associated with installing closed loop heat exchange system **10** are reduced. Manifold **20** may be manufactured from any conventional material having the structural integrity to withstand the intended operational pressures and environment, as well as having material compatible with other elements of the overall fluid-circulation and heat-transfer system. Additionally, manifold **20** provides the added benefit of improving the efficiency of the operation of such systems. By providing a balanced flow throughout closed loop heat exchange system **10**, manifold **20** enables efficient and balanced transfer of heat in the heat-exchange loops **18** and to media surrounding the loops.

**[0038]** Manifold **20** may also include auxiliary connection ports **42** and **44**. Ports **42** and **44** permit the connection of two or more manifolds **20** in series. Thus, with reference to FIG. **8**, conduits **46** and **48** join first and second manifolds **20** by connecting ports **25** and **44** and ports **23** and **42** respectively. The addition of a second manifold **20**, along with associated additional heat exchange loops **18** to closed-loop heat exchange system **10** increases the heat-exchange capacity of the system. If manifold **20** has auxiliary connection ports **42** and **44** but those ports are unused, then caps **52** and **54** will close off ports **42** and **44** respectively. Further, as depicted in FIG. **4**A, the selection of ports **23**, **25**, **42** and **44** will be determined by the configuration of closed loop heat exchange system **10**. Either end of plenums **22** and **24** will provide the desired balanced fluid flow through manifold **20**.

**[0039]** Additionally, manifold **20** will provide the balanced flow and pressure to closed loop heat exchange system **10** regardless of the flow direction. As a further alternative embodiment, input to manifold **20** may be either at ports **23**, **25** or at auxiliary ports **42**, **44**. The direction of flow and input/outlet will not alter the benefits provided by manifold **20** as substantially balanced flow and pressure will be achieved in varying configurations and operations.

**[0040]** FIGS. **9**A-C, **10**A-B and **11**A-B depict a space saving manifold **200**. In this embodiment, the fluid connections and the fluid flow paths correspond generally to the manifold **20** of FIGS. **2**-**8**. Thus, the only difference between manifold **200** and manifold **20** is the angular configuration of distribution plenum fluid outlet ports **26** and collection plenum inlet ports **28**. As depicted, distribution plenum fluid outlet ports **26** and collection plenum inlet ports **28** are not arranged as a linear alignment. As depicted in FIG. **10**A, upper ports **26** are in the same plane and project outward away from one another while the lower port **26** is located beneath the plane of the upper ports **26**. Thus, the configuration of ports **26** provide a size reduction for manifold **200** when compared to manifold **20**. While FIGS. **9**A and **9**C depict the pair of ports **26** above a single port **26**, a reverse configuration with two lower ports and one upper port is also contemplated.

**[0041]** The outward angle of the upper distribution plenum fluid outlet ports **26** and collection plenum inlet ports **28** may vary as needed by the application. In most instances, the outward angle may range from about 8° to about 20°. More typically, the angle may range between 10° and about 15°. As depicted in FIG. **10**C, the angle is about 12°.

**[0042]** FIGS. **11**A and **11**B depict alternative arrangements for retaining pipes **18** within manifolds **20** and **200**. As depicted in FIGS. **11**A and **11**B, snap rings **204** may be positioned within a portion of collection plenum inlet ports **28**. As known to those skilled in the art, snap rings **204** typically engage a recess or protrusion after the pipe has been positioned within snap ring **204**. As depicted in FIG. **10**A, snap ring **204** engages a snap ring groove **208**. Following positioning of pipe **18***b*, snap ring **204** expands to engage and retain pipe **18***b* in the desired position. Additionally, to provide the desired fluid tight connection, an O-ring **202** may be positioned around pipe **18***b*. When using O-ring **202**, an O-ring offset or groove **206** may be included within manifold **20** or **200**.

**[0043]** Installation of manifold **20** or **200** within heat exchange system **10** in the field includes several steps. As known to those skilled in the art, heat exchange loops **18** are placed in the ground at a predetermined depth based on the geographic location of the facility and the design of the closed-loop heat exchange system **10**. The method of placing heat exchange loops **18** may be any convenient operation known to those skilled in the art, including but not limited to directional boring or trenching. When using either manifold **20** or manifold **200**, the end points of heat exchange loops **18**, i.e. caps **19**, will typically be spaced apart by about 30 feet or more. While soil conditions will determine the final depth of heat exchange loops **18**, a depth of at least eight feet is typically desired. However, climates having temperatures extremes of hot or cold may require depths greater than eight feet. In some embodiments, the borehole or trench will have a depth at the midpoint of its length which is greater than the depth at either end of exchange loops **18**. Thus, following installation, heat exchange loops **18** define an arc as they pass through the subsurface soil. Typically, cap **19** of heat exchange pipes **18** will be at least two feet below the surface of the ground. While the foregoing discussion describes the installation of heat exchange pipes **18**, i.e. pipes **18***a* and **18***b*, installation of only pipe **18***a* may take place first followed by insertion of pipe **18***b* into **18***a*.

**[0044]** Following positioning of heat exchange pipes **18**, pipes **18***a* and **18***b* are secured to manifold **20** or **200**. The securement of pipes **18***a* and **18***b* will be the same regardless of the manifold used. Therefore, the following discussion will refer only to manifold **200**. Each pipes **18***a* is trimmed to length and aligned with each port **26**. Each pipes **18***b* is extended outward from its housing pipe **18***a* a distance sufficient to permit addition of coupling elements **202**. Coupling elements **202** include but are not limited to O-rings. At least one coupling element **202** is included on each pipe **18***b*. However, additional coupling elements **202** may be used depending upon the application. When using an O-ring as coupling element **202**, each pipe **18***b* will typically include a snap ring or other similar retention device **204**. As depicted in FIGS. **11**A and **11**B, coupling element **202** will normally be closer to collection plenum **24** than retention device **204**. Following installation of coupling element **202** and retention device **204** on each pipe **18***b*, manifold **20** is pushed onto pipe **18***b* or pipe **18***b* is forced into manifold **20** until engagement of pipe **18***b* with offset **28***b* of collection port **28***a* is achieved. Thus, the O-ring, as coupling element **202**, will engage O-ring offset **206** and retention device **204**, in the form of a snap ring, will engage snap ring groove **208**. While the sizing of O-ring offset **206** and snap ring groove **208** may vary from application to application, the configuration depicted in FIG. **10**A provides outer diameters for each corresponding to the outer diameter of port **26**. Therefore, O-ring offset **206** and snap ring groove **208** are not visible in FIG. **9**C.

**[0045]** Retention of pipe **18***a* in offsets **26***b* may be achieved by any convenient configuration. One typical retention method entails the positioning of stubs **18***aa* in offset **26***b* of port **26**. When using optional stubs **18***aa*, the proximate end of each pipe **18***a* may be joined to stubs **18***aa* using any convenient method known to those skilled in the art. One such method relies upon the use of electrofusion couplers **210**. Electrofusion couplers **210** are commonly used to join sections of plastic pipe to one another. When installed as shown in FIGS. **11**A and **11**B, electrofusion couplers **210** provide a secure, water tight connection of stub **18***aa* to pipe **18***a*. Following placement of pipe **18***b* in offset **28***b*, electrofusion couplers **210** are activated in a manner well known to those skilled in the art thereby securing pipe **18***a* to stub **18***aa*.

**[0046]** Following connection of heat exchange pipes **18** to manifold **200**, outflow line **16** and return line **17** are secured to manifold **200** at primary inlet port **23** and primary outlet port **25** respectively. The closed-loop heat exchange system **10** will be pressure tested to identify any leaks. After completion of pressure testing and filling of closed-loop heat exchange system **10** with the desired heat exchange liquid, closed-loop heat exchange system **10** is ready for use. Depending on the application, manifold **20** and **200** may optionally be buried.

**[0047]** Other embodiments of the present invention will be apparent to one skilled in the art. As such, the foregoing description merely enables and describes the general uses and methods of the present invention. Accordingly, the following claims define the true scope of the present invention.

What is claimed is:

**1**. A manifold comprising:

a distribution plenum having a first primary inlet and at least one distribution plenum fluid outlet port;

a collection plenum having a first primary outlet and at least one collection plenum fluid inlet port;

wherein the distribution plenum and the collection plenum are integrated with one another such that the at least one distribution plenum fluid outlet port and the at least one collection plenum fluid inlet port share the same central axis.

**2**. The manifold of claim **1**, wherein the at least one distribution plenum fluid outlet port has a cross-sectional area and the at least one collection plenum fluid inlet port has a cross-sectional area, wherein the cross-sectional area of the at least one distribution plenum fluid outlet port is about twice the cross-sectional area of the at least one collection plenum fluid inlet port.

**3**. The manifold of claim **1**, wherein the at least one distribution plenum fluid outlet port defines a fluid flow path and wherein at least one distribution plenum fluid outlet port has an offset area which is outside of the fluid flow path, the offset area having a width.

**4**. The manifold of claim **1**, wherein the at least one collection plenum fluid inlet port defines a fluid flow path and wherein the at least one collection plenum fluid inlet port has an offset area which is outside of the fluid flow path.

**5**. The manifold of claim **3**, further comprising a stub pipe positioned within the at least one distribution plenum fluid outlet port, the stub pipe having a thickness corresponding to the width of the offset area of the at least one distribution plenum fluid outlet port.

**6**. The manifold of claim **1**, wherein the distribution plenum and the collection plenum are parallel to one another and a first central passageway located in the distribution plenum is parallel to a second central passageway located in the collection plenum.

**7**. The manifold of claim **1**, further comprising a first central passageway located in the distribution plenum and a second central passageway located in the collection plenum, wherein the at least one collection plenum fluid inlet port intersects the first central passageway within the distribution plenum and the second central passageway within the collection plenum.

**8**. The manifold of claim **1**, wherein the manifold has at least three pair of distribution plenum fluid outlet ports and collection plenum fluid inlet ports, wherein each pair of distribution plenum fluid outlet ports and collection plenum fluid inlet ports share a central axis.

**9**. The manifold of claim **8**, wherein at least two pairs of distribution plenum fluid outlet ports and collection plenum fluid inlet ports are in a first horizontal plane and at least one pair of distribution plenum fluid outlet ports and collection plenum fluid inlet ports is above or below the first horizontal plane.

**10**. The manifold of claim **9**, wherein the at least two pairs of distribution plenum fluid outlet ports and collection plenum fluid inlet ports and the at least one pair of distribution plenum fluid outlet ports and collection plenum fluid inlet ports positioned above or below the first horizontal plane project outward the manifold at different angles.

**11**. The manifold of claim **9**, wherein the at least two pairs of distribution plenum fluid outlet ports and collection plenum fluid inlet ports project outward from the first primary inlet at an angle between about 8 degrees and about 20 degrees.

**12**. The manifold of claim **9**, wherein the at least two pairs of distribution plenum fluid outlet ports and collection plenum fluid inlet ports project outward from the first primary inlet at an angle between about 10 degrees and about 15 degrees.

**13**. A manifold and heat exchange pipes for a balanced flow heat exchange system comprising:

a distribution plenum having a first primary inlet and at least one distribution plenum fluid outlet port;

a collection plenum having a first primary outlet and at least one collection plenum fluid inlet port;

wherein the distribution plenum and the collection plenum are integrated with one another such that the at least one distribution plenum fluid outlet port and the at least one collection plenum fluid inlet port share the same central axis;

a first heat exchange pipe positioned within the at least one distribution plenum fluid outlet port, the first heat exchange pipe having a first interior surface, a first exterior surface, a first inside diameter and a first thickness;

a second heat exchange pipe positioned within the at least one collection plenum fluid inlet port, the second heat exchange pipe having a second interior surface, a second exterior surface, a second inside diameter, an interior cross-sectional area and a second thickness;

wherein the second heat exchange pipe passes through the first heat exchange pipe and wherein the first interior surface of the first heat exchange pipe and the second exterior surface of the second heat exchange pipe define an annulus;

wherein the annulus has a cross-sectional area which is about equal to a cross-sectional area of the interior cross-sectional area of the second heat exchange pipe.

**14**. The manifold and heat exchange pipes for a balanced flow heat exchange system of claim **13**, wherein the first heat exchange pipe has a first terminal end and the second heat exchange pipe has a second terminal end and further comprising a cap covering the first and second terminal ends, the cap providing fluid communication between the annulus and the interior cross-sectional area of the second heat exchange pipe.

**15**. The manifold and heat exchange pipes for a balanced flow heat exchange system of claim **13**, wherein the at least one distribution plenum fluid outlet port defines a first fluid flow path and wherein at least one distribution plenum fluid outlet port has a first offset area which is outside of the first fluid flow path, the first offset area having a width;

wherein the first thickness of the first heat exchange pipe corresponds to the width of the first offset area and wherein the fluid flow path of the at least one distribution plenum fluid outlet port continues from the at least one distribution plenum fluid outlet port into the first heat exchange pipe.

**16**. The manifold and heat exchange pipes for a balanced flow heat exchange system of claim **13**, wherein the at least one collection plenum fluid inlet port defines a second fluid flow path and wherein the at least one collection plenum fluid inlet port has a second offset area which is outside of the second fluid flow path;

wherein the second thickness of the second heat exchange pipe corresponds to the width of the second offset area and wherein the second fluid flow path of the at least one collection plenum fluid inlet port continues from the at least one collection plenum fluid inlet port into the second heat exchange pipe.

**17**. The manifold and heat exchange pipes for a balanced flow heat exchange system of claim **13**, wherein the distribution plenum and the first heat exchange pipe and the collection plenum and the second heat exchange pipe provide balanced flow through the heat exchange system.

**18**. A manifold and heat exchange pipes for a balanced flow heat exchange system comprising:

a distribution plenum having a first primary inlet and at least one distribution plenum fluid outlet port;

a collection plenum having a first primary outlet and at least one collection plenum fluid inlet port;

wherein the distribution plenum and the collection plenum are integrated with one another such that the at least one distribution plenum fluid outlet port and the at least one collection plenum fluid inlet port share the same central axis;

a first stub pipe positioned within the at least one distribution plenum fluid outlet port, the first stub pipe having a first interior surface, a first exterior surface, a first inside diameter and a first thickness.

**19**. The manifold and heat exchange pipes for a balanced flow heat exchange system of claim **18** further comprising:

a second heat exchange pipe positioned within the at least one collection plenum fluid inlet port, the second heat exchange pipe having a second interior surface, a second exterior surface, a second inside diameter, an interior cross-sectional area and a second thickness;

wherein the second heat exchange pipe passes through the first stub pipe and wherein the first interior surface of the first heat exchange pipe and the second exterior surface of the second heat exchange pipe define an annulus;

wherein the annulus has a cross-sectional area which is about equal to a cross-sectional area of the interior cross-sectional area of the second heat exchange pipe.

**20**. The manifold and heat exchange pipes for a balanced flow heat exchange system of claim **19**, wherein the at least one distribution plenum fluid outlet port defines a first fluid flow path and wherein at least one distribution plenum fluid outlet port has a first offset area which is outside of the first fluid flow path, the first offset area having a width;

wherein the first thickness of the first stub pipe corresponds to the width of the first offset area and wherein the fluid flow path of the at least one distribution plenum fluid outlet port continues from the at least one distribution plenum fluid outlet port into the first stub pipe.

**21**. The manifold and heat exchange pipes for a balanced flow heat exchange system of claim **19**, wherein the at least one collection plenum fluid inlet port defines a second fluid flow path and wherein the at least one collection plenum fluid inlet port has a second offset area which is outside of the second fluid flow path;

wherein the second thickness of the second heat exchange pipe corresponds to the width of the second offset area and wherein the second fluid flow path of the at least one collection plenum fluid inlet port continues from the at least one collection plenum fluid inlet port into the second heat exchange pipe.

**22**. The manifold and heat exchange pipes for a balanced flow heat exchange system of claim **19**, further comprising:

a first heat exchange pipe secured to the first stub pipe, the first heat exchange pipe having a third thickness, the third thickness is about equal to the first thickness of the first stub pipe;

wherein the first heat exchange pipe has a first terminal end and the second heat exchange pipe has a second terminal end and further comprising a cap covering the first and second terminal ends, the cap providing fluid communication between the annulus and the interior cross-sectional area of the second heat exchange pipe.

**23**. The manifold and heat exchange pipes for a balanced flow heat exchange system of claim **22**, wherein the distribution plenum, the first stub pipe and the first heat exchange pipe have a first volume and the collection plenum and the second heat exchange pipe have a second volume, wherein the first and second volumes are about equal.

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