US 20070022754A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2007/0022754 A1
Perkins et al. (43) Pub. Date: Feb. 1, 2007

(54) THERMAL STORAGE UNIT AND METHODS FOR USING THE SAME TO HEAD A FLUID

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(21) Appl. No.: 11/197,300

(22) Filed: Aug. 3, 2005

**Related U.S. Application Data**

(63) Continuation of application No. 10/738,825, filed on Dec. 16, 2003, now Pat. No. 6,955,050.

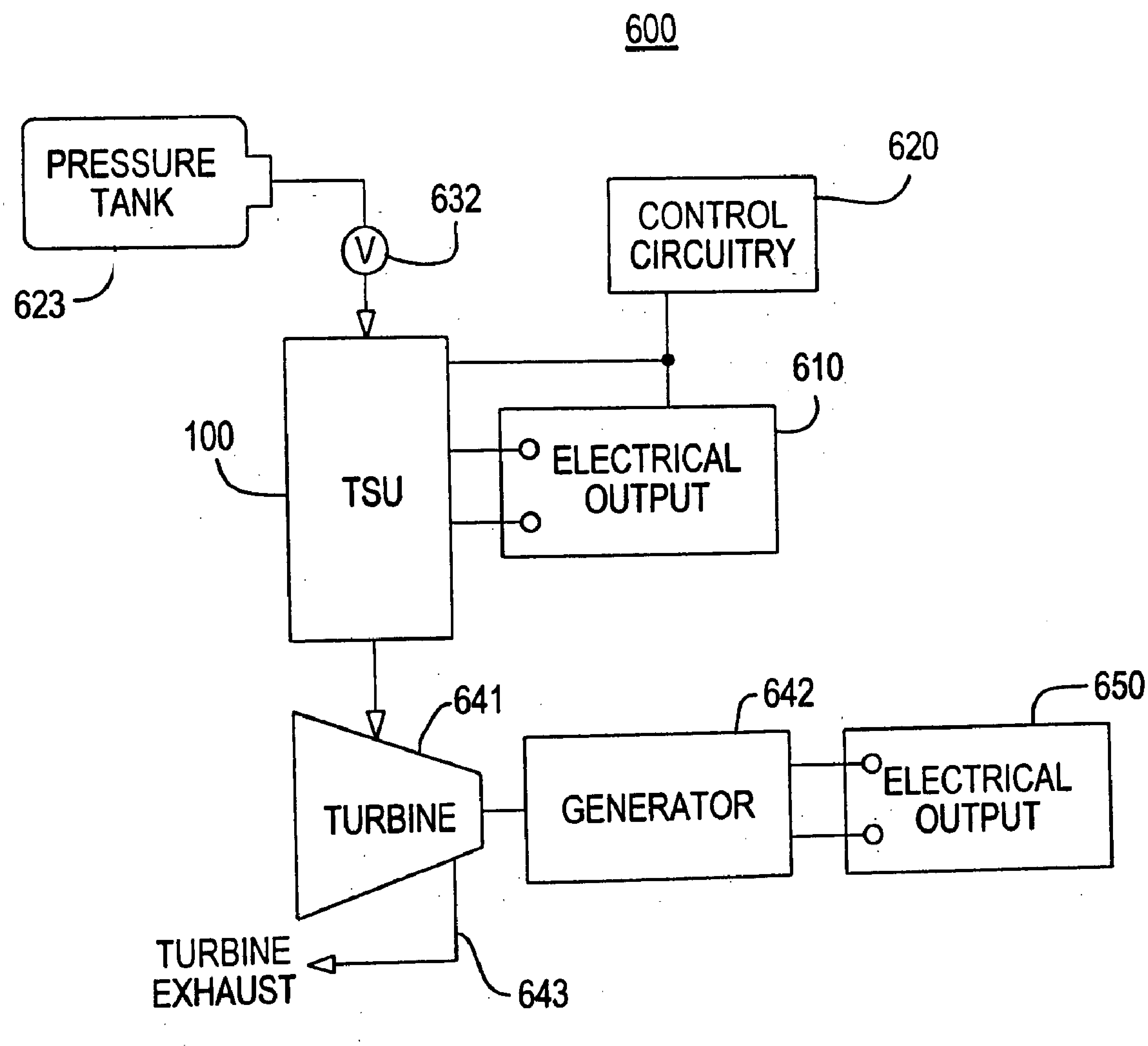
**Publication Classification**

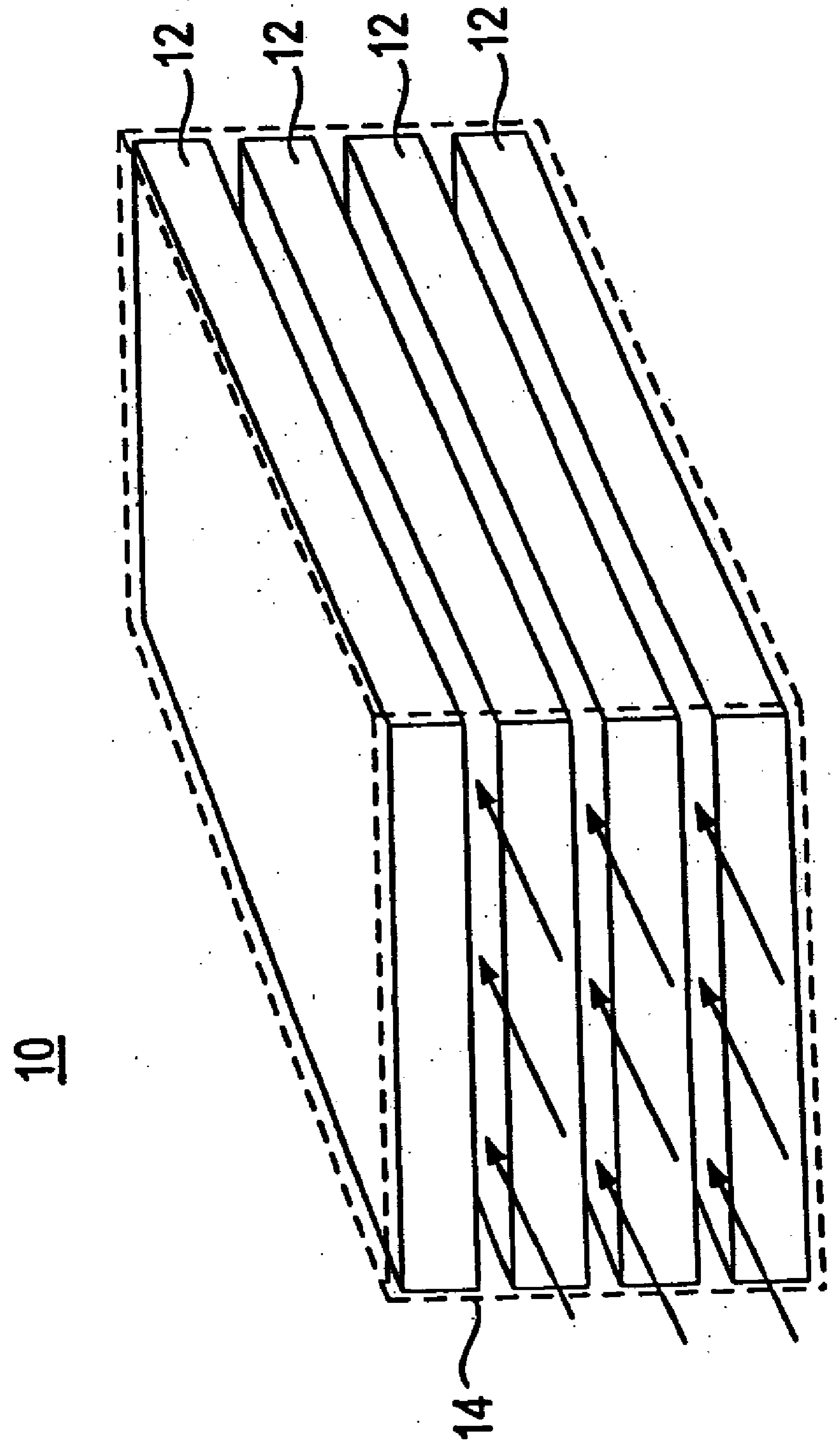
(51) Int. Cl.
*F01K 13/02* (2006.01)

(52) U.S. Cl. ........................................ 60/646

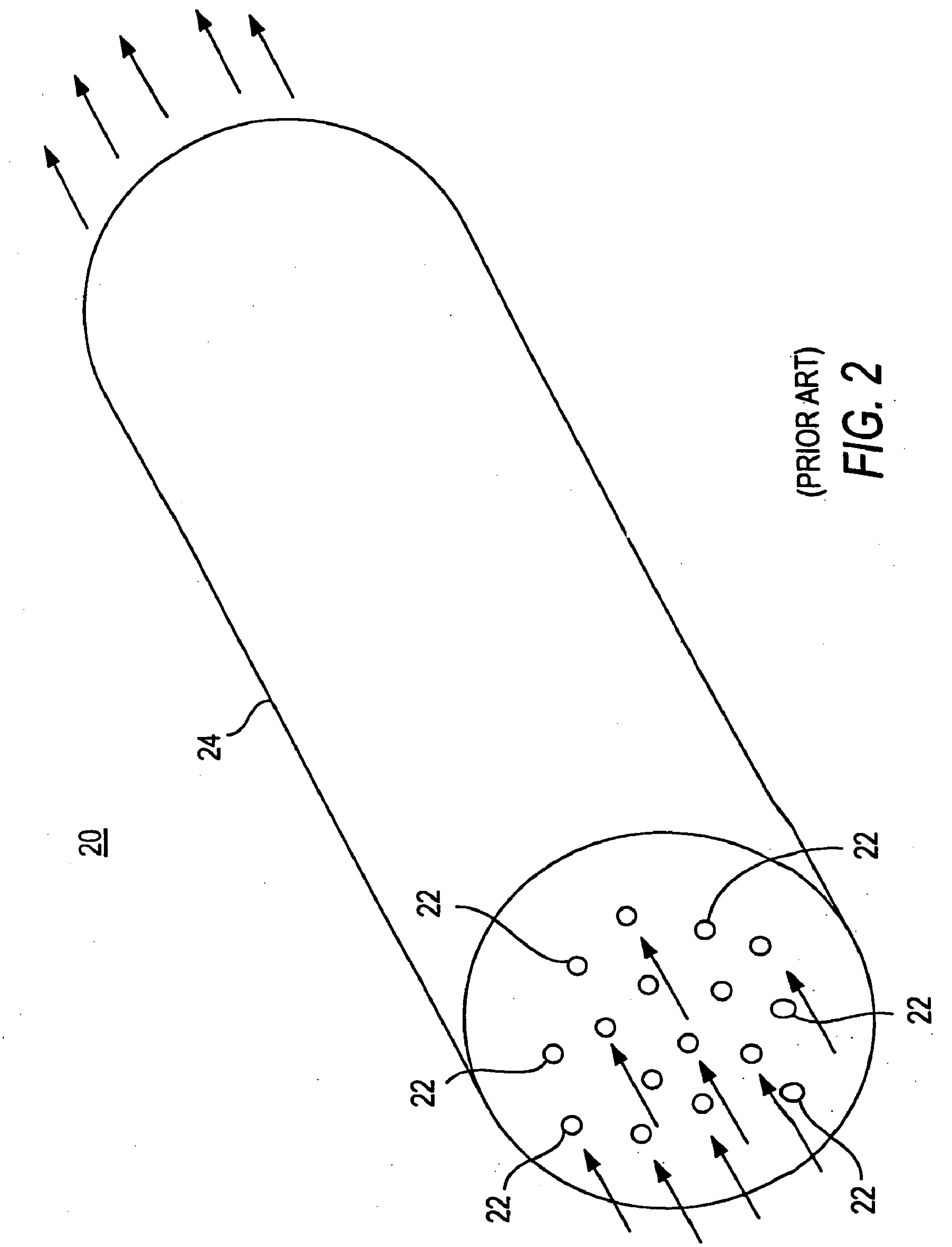
(57) ABSTRACT

A thermal storage unit having at least one annular flow channel formed between an inner and outer member is provided. The thermal storage unit uses conventional mill products to create annular flow channels that economically maximize the surface area of flow in contact with the thermal mass included in the inner and outer members. This enables the thermal storage unit to economically provide heat storage as well as effective heat delivery and pressure containment for a fluid flowing through the annular channel.






(PRIOR ART)
FIG. 1




(PRIOR ART)
FIG. 2

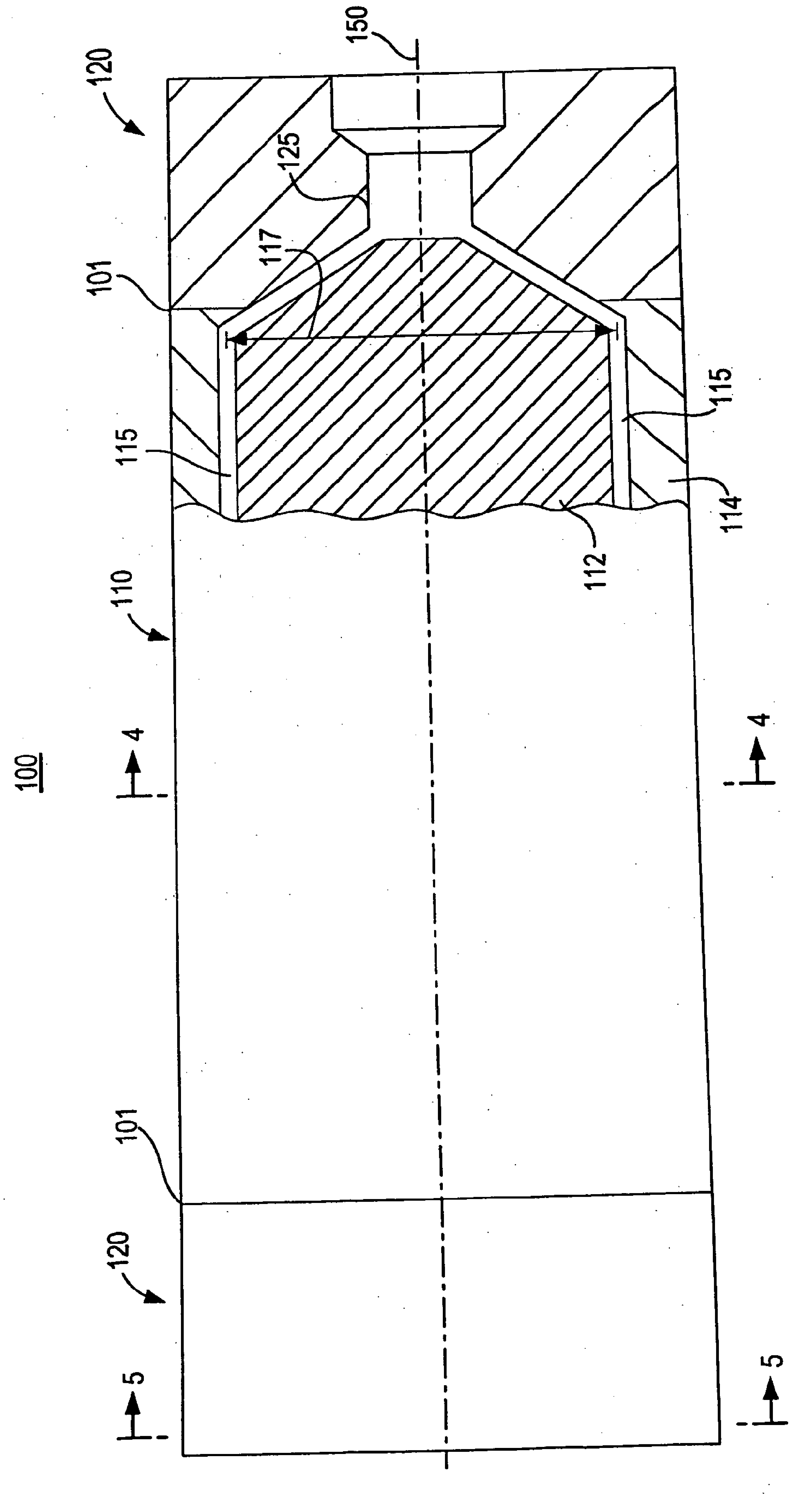



FIG. 3

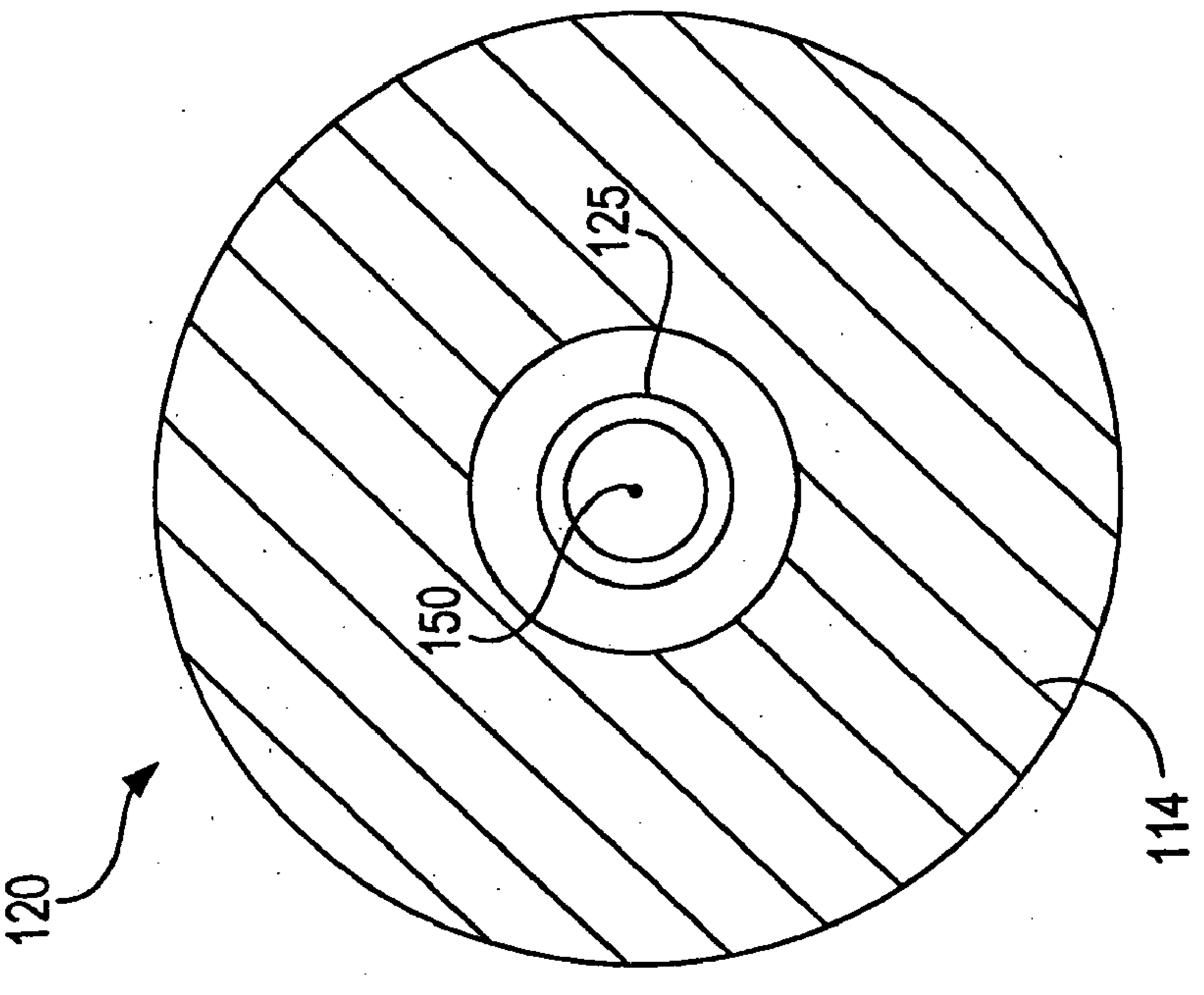



FIG. 5

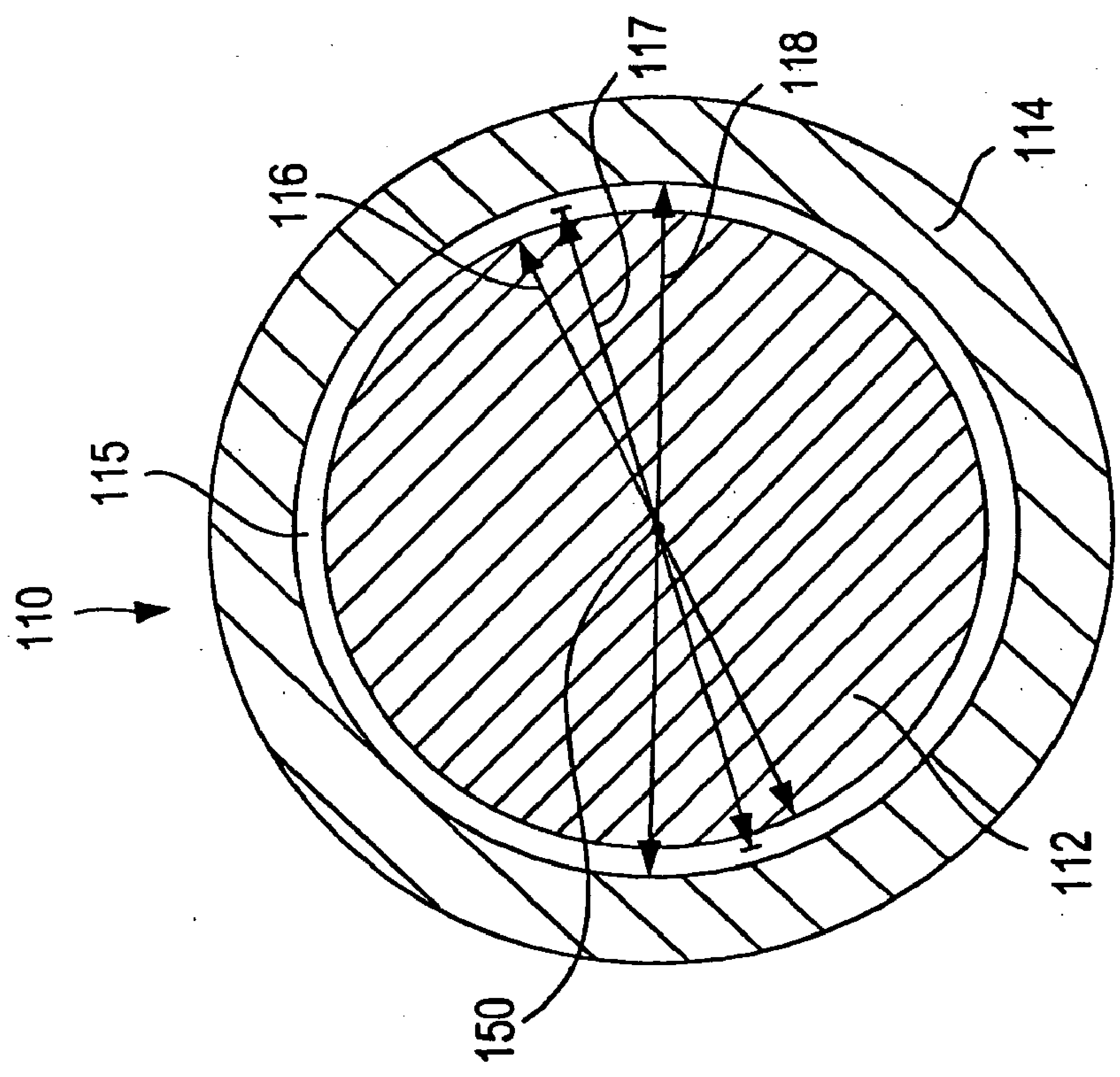



FIG. 4

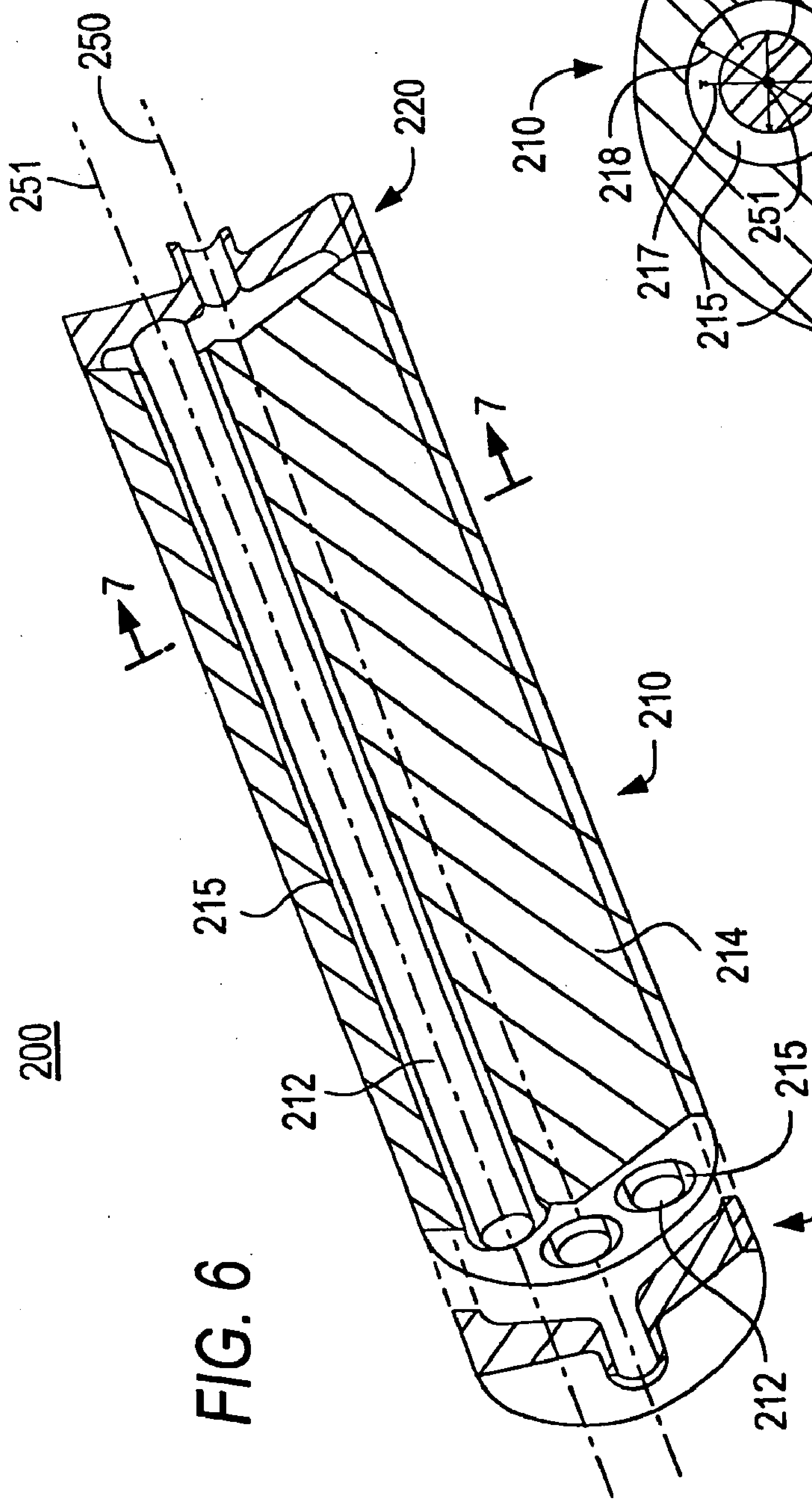

200
251
250
220
7
7
210
215
214
212
215
220
212

FIG. 6

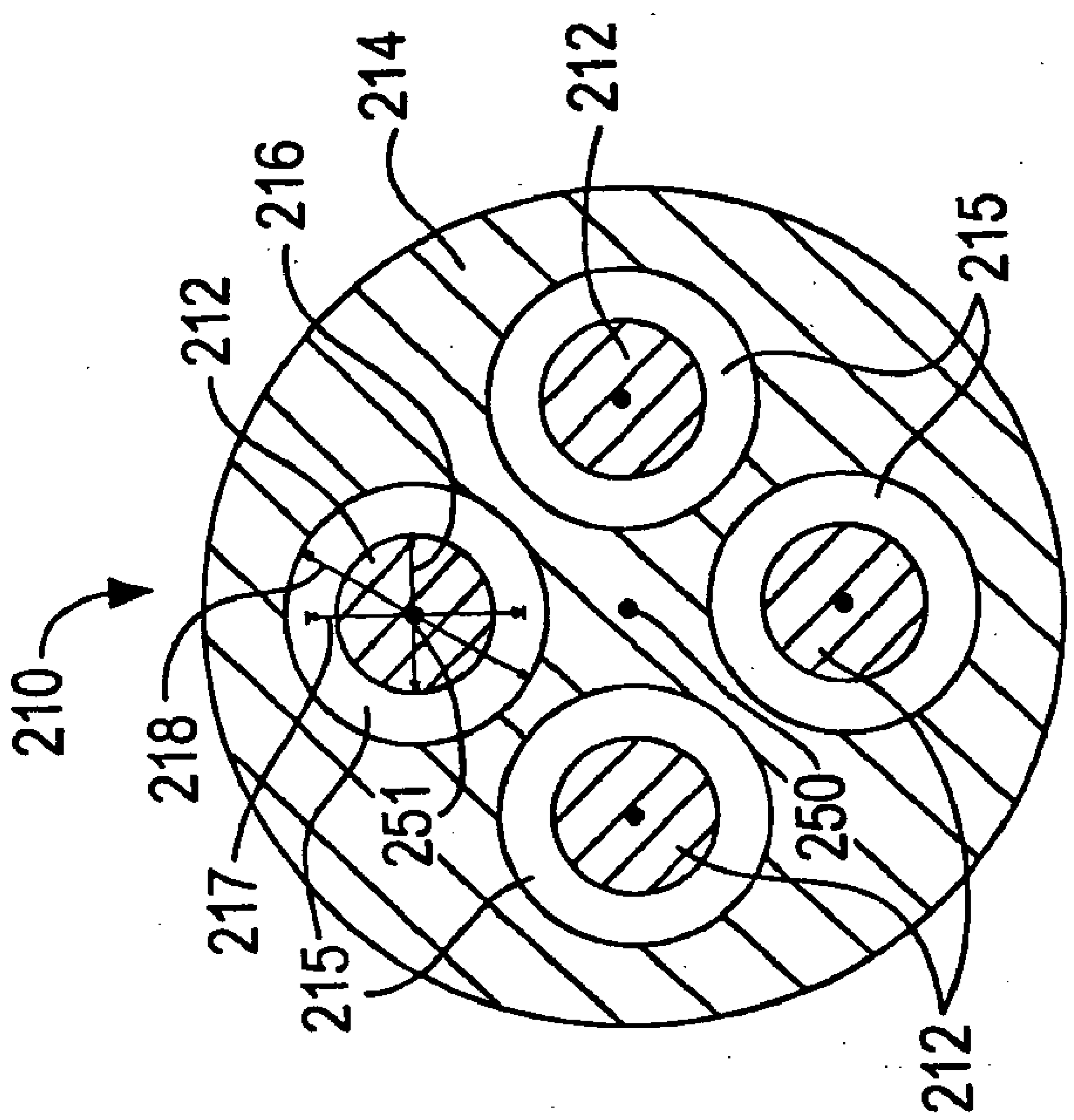

214
212
216
215
212
210
218
217
251
250
215
212

FIG. 7

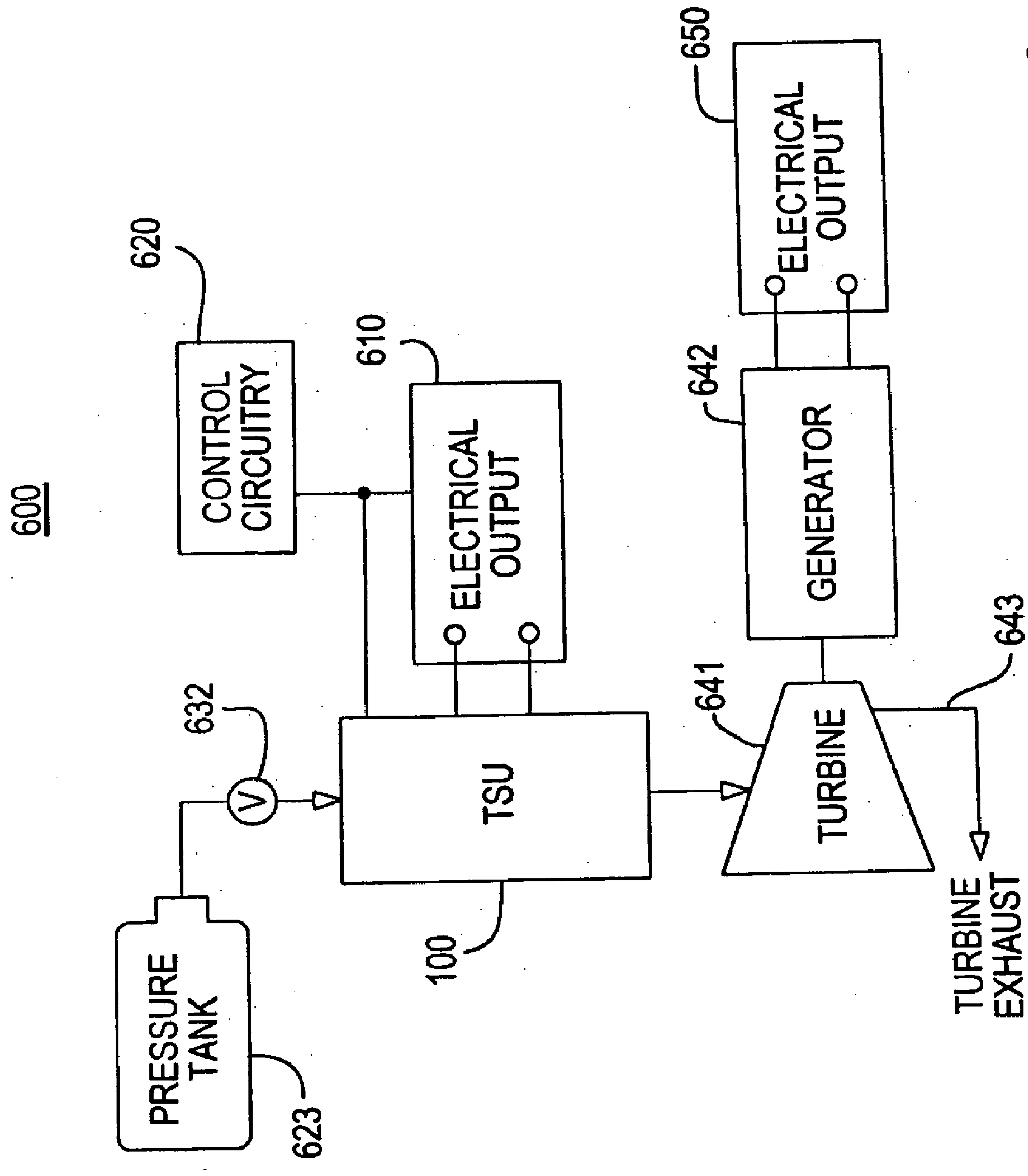

600
CONTROL CIRCUITRY
620
610
ELECTRICAL OUTPUT
650
ELECTRICAL OUTPUT
642
GENERATOR
632
V
PRESSURE TANK
623
TSU
100
641
TURBINE
643
TURBINE EXHAUST

FIG. 8

## THERMAL STORAGE UNIT AND METHODS FOR USING THE SAME TO HEAD A FLUID

### BACKGROUND OF THE INVENTION

[0001] This invention relates to thermal storage units (TSUs). More particularly, this invention relates to TSUs that provide sensible heat thermal energy storage and delivery in a way that increases efficiency and reduces costs compared to known TSUs.

[0002] TSUs are well known and are often used in power delivery systems, such as compressed air storage (CAS) systems and thermal and compressed air storage (TACAS) systems. Such systems, often used to provide an available source of electrical power, often use compressed air to drive a turbine which powers an electrical generator.

[0003] In TACAS systems, it is desirable to heat the compressed air prior to reaching the inlet port of the turbine. It is known that heated air, as opposed to ambient or cool air, enables the turbine to operate more efficiently. Therefore, a mechanism or system is needed to heat the air before providing it to the turbine. One approach is to use a suitable type of fuel-combustion system. Another approach is to use a TSU. While fuel-combustion systems usually emit polluting gases, TSUs may be preferable over fuel-combustion systems at least because they are not associated with such harmful emissions.

[0004] Although TSUs may offer advantages over fuel-combustion systems, existing TSUs have several shortcomings, as discussed below.

[0005] One known configuration of a TSU is shown in FIG. **1**. TSU **10** of FIG. **1** includes heated parallel plates **12** contained within housing **14** to create channels through which compressed air may flow. The heat transfer area and the gap between plates **12** may be adjusted for optimum heat transfer conditions. Such a TSU, however, is not optimally suited for high pressure operation as these plates do not provide optimum pressure containment for the compressed air, and instead result in leakage flow between plates **12** and housing **14**.

[0006] Another known TSU uses tube flow through elongated cavities embedded in a solid medium. As shown in FIG. **2**, compressed air travels through through-holes **22**, which are bored out of bar **24**. Although tube flow, as provided by TSU **20** of FIG. **2**, may provide more desirable pressure containment compared to channel flow TSU **10** of FIG. **1**, it involves high fabrication costs. This is because it is usually costly to drill a plurality of small-diameter holes that extend throughout the entire length of a solid medium.

[0007] Therefore, it can be seen that the TSUs shown in FIGS. **1** and **2** fail to provide means for effectively containing and delivering hot and compressed air in a manner that is cost beneficial.

[0008] In view of the foregoing, it is an object of this invention to provide a low-cost TSU that provides efficient heat storage, heat delivery and pressure containment.

### SUMMARY OF THE INVENTION

[0009] This and other objects of the present invention are accomplished in accordance with the principles of the present invention by providing a TSU having at least one flow channel disposed annularly about an axis that is substantially parallel to the TSU's longitudinal axis. The annular channel may be contained between an inner member and an outer member, both of which may include thermal mass or thermal storage material having desirable energy or heat storage properties and may be fabricated using standard mill products. The annular channel may be coupled to a port on each end of the channel for either providing fluid thereto or projecting fluid therefrom. In one embodiment of the present invention, the TSU may include a single annular flow channel disposed about the TSU's longitudinal axis. In another embodiment of the present invention, the TSU may include multiple parallel annular flow channels, each being contained between the outer member and a different inner member.

[0010] The inner and outer members of the TSU may be heated to effectively heat a fluid flowing through the annular channel. Efficient heat transfer is realized with the annular channel because the ring-like channel maximizes the surface area of fluid contact with the inner and outer members. In addition to providing energy storage and efficient heat transfer, the outer member provides structural support for the TSU, thereby enabling it to contain pressurized fluids. For example, the TSU may be used in a TACAS system whereby compressed air may be sensibly heated in the TSU. The heated and compressed air may then drive a turbine which powers an electrical generator to provide an electrical output.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The above and other features of the present invention, its nature and various advantages will be more apparent upon consideration of the following detailed description, taken in conjunction with the accompanying drawings, in which like reference characters refer to like parts throughout, and in which:

[0012] FIG. **1** is a top perspective view of a known thermal storage unit;

[0013] FIG. **2** is a top perspective view of another known thermal storage unit;

[0014] FIG. **3** is a partial sectional view of a thermal storage unit in accordance with the principles of the present invention;

[0015] FIG. **4** is a cross-sectional view of the thermal storage unit of FIG. **3**, taken generally from line **4-4** of FIG. **3**;

[0016] FIG. **5** is a cross-sectional view of the thermal storage unit of FIG. **3**, taken generally from line **5-5** of FIG. **3**;

[0017] FIG. **6** is a partial perspective view of another thermal storage unit in accordance with the principles of the present invention;

[0018] FIG. **7** is a cross-sectional view of the thermal storage unit of FIG. **6**, taken generally from line **7-7** of FIG. **6**; and

[0019] FIG. **8** is a partial schematic diagram of a thermal and compressed air storage system employing a thermal storage unit in accordance with the principles of the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

[0020] FIG. **3** depicts an embodiment of thermal storage unit (TSU) **100**, in accordance with the principles of the present invention. TSU **100** may be cylindrical in shape and may have longitudinal axis **150**. Persons skilled in the art will appreciate that the general shape of TSU **100** is not limited to cylinders and may be constructed to fulfill any design criteria.

[0021] TSU **100** may include three main compartments, namely, middle portion **110** and end portions **120**. Middle portion **110** may be defined as the portion of TSU **100** that is between lines **101**, whereas end portions **120** may be defined as the portions of TSU **100** that extend beyond lines **101** to both ends of TSU **100**. When fluid is applied to TSU **100**, it is directed into one of end portions **120**, flows through middle portion **110**, and is directed out of the other end portion **120**. Fluid may be matter in the liquid, gas or plasma phase.

[0022] When fluid is routed through middle portion **110**, it flows in a ring-like channel, which is referred to as annular flow channel **115**. Annular channel **115** may extend generally along middle portion **110**, between outer member **114** and inner member **112**. Annular channel **115** may extend along the length of middle portion **110**, in a direction that is substantially parallel to longitudinal axis **150**.

[0023] FIG. **4** shows a cross-sectional view taken along line **4-4** of FIG. **3**. Annular channel **115** may have an inner diameter and an outer diameter. Inner diameter **116** and outer diameter **118** of FIG. **4** define the cross-sectional area of annular channel **115**. The portion of inner member **112** contained in middle portion **110** may have a cylindrical outer surface, thereby providing a basis for inner diameter **116** of annular channel **115** (i.e. the diameter of inner member **112**). Similarly, the inner surface of outer member **114**, which may be cylindrically shaped and which is contained in middle portion **110**, provides a basis for outer diameter **118** of annular channel **115** (i.e. the diameter of outer member **114**). The length of a mean diameter (depicted by dotted line **117**) of annular channel **115** may be calculated as the mean value of the length of inner and outer diameters **116** and **118**.

[0024] Referring back to FIG. **3**, because inner member **112** extends partially into end portions **120**, and because outer member **114** extends through the entire length of TSU **100**, annular channel **115** may also partially extend into end portions **120**. Starting approximately at each end of middle portion **110**, mean diameter **117** of annular channel **115** may taper into end portion **120**, in a direction parallel to longitudinal axis **150**.

[0025] End portions **120**, which may be identical, may each include a hollow or tubular enclosure, namely, port **125**, within a portion of outer member **114** that extends into each of the end portions. Port **125** may be coupled to the portion of annular channel **115** that extends into the end portion for either providing fluid thereto or projecting fluid therefrom. In this arrangement, annular channel **115** may decrease in mean diameter from a point within TSU **100** (e.g., a point proximal to line **101**) to the point on the end portion where port **125** couples to annular channel **115**. This arrangement enables fluid delivery to and from the TSU. Port **125** may be also seen in FIG. **5**, which shows a cross-sectional view taken along line **5-5** of FIG. **3**. Port **125** may be a tubular aperture (e.g., an inlet or outlet) for facilitating the delivery or projection of fluid to or from TSU **100**.

[0026] In a preferred embodiment of the present invention, inner member **112** may be constructed from solid material(s) that have adequate thermal conductivity and other desirable thermal properties such as high volumetric heat capacity. Outer member **114** may be constructed from the same material(s) as inner member **112**. Therefore, both inner and outer members **112** and **114** may provide thermal mass for energy storage. Alternatively, outer member **114** may be constructed from material(s) capable of withstanding high pressure, in addition to possessing desirable thermal properties. Such materials may include iron, steel, aluminum, any alloys thereof or any other suitable material(s).

[0027] According to the principles of the present invention, TSU **100** may be heated to a desired temperature by heating inner and outer members **112** and **114**. Fluid may then be heated by routing it through TSU **100** such that it enters one of ports **125** at one end, flows through annular channel **115**, and exits through port **125** at the opposite end.

[0028] Inner member **112** and/or outer member **114**, may be heated through radiation by means of an external or internal heater. For example, a ceramic fiber heater that annularly surrounds—without coming into contact with—TSU **100** may heat both inner and outer members **112** and **114** through radiation when actuated. Alternatively, one or more heating rods may be placed into one or more cavities extending through at least a portion of or the entire length of TSU **100**. When such heating rods are actuated, they radiate heat energy to heat both inner and outer members **112** and **114**.

[0029] Due to the thermal conductivity of the inner and outer members **112** and **114**, heat energy is effectively conducted through these members. Moreover, because annular channel **115** maximizes the surface area of fluid contact with the thermal mass in inner and outer members **112** and **114**, the fluid flowing in the channel may be sensibly heated through convection from inner member **112** and/or outer member **114** to the fluid. Accordingly, heating either member or both enables the efficient heating of the fluid flowing through the channel. Thus, when fluid having a predetermined temperature (e.g., ambient temperature) is supplied to TSU **100**, its temperature rises as it flows through annular channel **115** formed between inner and outer members **112** and **114**.

[0030] Persons skilled in the art will appreciate that electronic circuitry (not shown) may be used to monitor the temperature of TSU **100** and control the mechanism (e.g., the external ceramic heater or internal heating rods) used to heat TSU **100**. A more detailed discussion of such electronics is provided below in connection with FIG. **8**.

[0031] An example of a fluid that may be routed through TSU **100** is compressed air. Compressed air may be heated using TSU **100**, as discussed above. Moreover, TSU **100** provides structural integrity against pressure exerted from the compressed air flowing in the channel. This is due to the fact that outer member **114**, which contains material capable of withstanding high pressure, cylindrically surrounds the annular channel, thereby containing the pressure exerted by the air on the outer member. Therefore, not only is TSU **100** adequate for providing heat storage, TSU **100** is conducive to high pressure operation, unlike the parallel-plate channel flow TSU **10** of FIG. **1**.

[**0032**] Moreover, unlike drilling multiple small-diameter holes that extend through the entire length of a bar in order to implement tube flow as shown in connection with TSU **20** of FIG. **2**, fabricating TSU **100** may be significantly easier and less costly. This is because TSU **100** may be fabricated using conventional mill products having cylindrical shapes such as pipes, tubes and round bars. For example, inner member **112** may be a round bar that is machined to achieve the desired diameter and profile.

[**0033**] FIG. **6** depicts an alternative embodiment of thermal storage unit (TSU) **200** that utilizes multiple annular flow channels, in accordance with the principles of the present invention. TSU **200** may be cylindrical in shape and may have longitudinal axis **250**. Persons skilled in the art will appreciate that the general shape of TSU **200** is not limited to cylinders and may be constructed to fulfill any design criteria.

[**0034**] Like TSU **100** of FIG. **3**, TSU **200** may include three main compartments, namely, middle portion **210** and end portions **220**. End portions **220**, which may be identical, may each include a hollow or tubular enclosure, namely, port **225**, for either providing fluid to middle portion **210** or projecting fluid therefrom. When fluid is routed through middle portion **210**, it flows through multiple annular flow channels **215**. Annular flow channels **215** may be parallel to one another and may extend generally along middle portion **210**.

[**0035**] Each one of annular channels **215** may be disposed annularly about an axis that is substantially parallel to longitudinal axis **250**, such as axis **251**. Each annular channel **215** may be formed by drilling or casting a relatively large-diameter hole in a round bar, which may be referred to as outer member **214**, and inserting a smaller round bar, which may be referred to as inner member **212**, such that each inner member **212** extends at least along the length of middle portion **210**. Because the holes in outer member **214** are relatively large, at least compared to the holes bored through TSU **20** of FIG. **2**, TSU **200** can be fabricated relatively easily using conventional mill products. Not only does TSU **200** benefit from ease of manufacturing, it also provides efficient energy storage, heat transfer and pressure containment consistent with that discussed above in connection with TSU **100** of FIG. **1**.

[**0036**] FIG. **8** shows a cross-sectional view taken along line **7-7** of FIG. **6**. Each one of annular channels **215** may be formed between the inner cylindrical surface of a hole in outer member **214** and the outer cylindrical surface of one of inner members **212**. Each inner cylindrical surface in outer member **214** provides a basis for outer diameter **218** in one of the annular channels, while each outer cylindrical surface of inner members **212** provides a basis for inner diameter **216** in the same annular flow channel. The length of a mean diameter (depicted by dotted line **217**) of each annular channel **215** may be calculated as the mean value of the length of inner and outer diameters **216** and **218** for the annular channel.

[**0037**] In a preferred embodiment of the present invention, each mean diameter of annular channels **215** may be substantially equal in length. Moreover, inner and outer members **212** and **214** may be constructed from the same material as members **112** and **114** of TSU **100** of FIG. **3**, and may be heated using the same means described for heating TSU **100**. Fluid may therefore be heated by routing it through heated TSU **200** such that it enters one of ports **225** at one end, flows through annular channel **215**, and exits through port **225** at the opposite end.

[**0038**] The present invention may be used in many applications. FIG. **8** illustrates one such application. More specifically, FIG. **8** shows a thermal and compressed air storage (TACAS) system **600** for providing output power utilizing TSU **100** of FIG. **3**, described above. For example, FIG. **8** may represent a backup energy system that provides backup power to a load in the event of a disturbance in the supply of power from another power source (e.g., utility power failure.) Naturally, TSU **200** of FIG. **6** may be used instead of TSU **100** in TACAS system **600**.

[**0039**] The following discussion of TACAS system **600** is not intended to be a thorough explanation of the components of a TACAS, but rather an illustration of how TSU **100** or **200** can enhance the performance of a TACAS system. For a detailed description of a TACAS system, see commonly-assigned, co-pending U.S. patent application Ser. No. 10/361,728, filed Feb. 5, 2003, which is hereby incorporated by reference herein in its entirety.

[**0040**] As shown in FIG. **8**, TACAS system **600** includes storage or pressure tank **623**, valve **632**, TSU **100**, electrical input **610**, turbine **641**, generator **642** and electrical output **650**. When electric power is needed from system **600**, compressed air from pressure tank **623** may be routed through valve **632** to TSU **100**. TSU **100** may heat the compressed air before it is provided to turbine **641**.

[**0041**] The hot air emerging from TSU **100** may flow against the turbine rotor (not shown) of turbine **641** and drive turbine **641**, which may be any suitable type of turbine system (e.g., a radial-flow turbine). In turn, turbine **641** may drive electrical generator **642**, which produces electric power and provides it to electrical output **650**.

[**0042**] Also shown in FIG. **8** is turbine exhaust **643** (e.g., the exhaust gases emerging from turbine **641**). Turbine exhaust **643** may be vented through an exhaust pipe (not shown), or simply released to recombine with atmospheric air.

[**0043**] Not only is system **600** advantageous because it uses a relatively inexpensive and efficient TSU, it is also non-polluting. That is because, unlike conventional systems that use fuel-combustion systems to provide hot air to the turbine, it does not require a fuel supply to heat the air that is being supplied to turbine **641**. Instead, TSU **100** may be powered by electrical input **610**, which provides the energy needed to heat the compressed air, while providing effective pressure containment. For example, TSU **100** may include an external or internal radiant heater, as discussed above, which may be powered by electrical input **610**. System **600** therefore provides the benefits of heating compressed air from pressure tank **623** before it is supplied to turbine **641**, without producing the harmful emissions associated with combustion systems.

[**0044**] It will also be understood by persons skilled in the art that, alternatively, the thermal storage material of TSU

100 may be heated by any other suitable type of heating system. For example, a resistive heater may provide a heat source that is in physical contact with the thermal storage material of TSU **100** and may heat this material to a predetermined temperature. Alternatively, electrically conductive thermal storage materials, such as iron, may be heated inductively using induction heating circuitry that causes current to circulate through and heat the thermal storage material of TSU **100**. Thus, the invention is not limited to the specific heating manners discussed above.

[**0045**] TACAS system **600** may also include control circuitry **620** which may be coupled to both TSU **100** and electrical input **610**. Control circuitry **620** may include means for measuring the temperature of TSU **100**. Control circuitry **620** may also include electric circuitry for controlling the temperature of TSU **100**. Control circuitry **620** may control the temperature of TSU **100** by, for example, controlling the electric power provided to the heat source. This may be achieved by providing instructions to electrical input **610**, such as instructions to activate, deactivate, increase or decrease the output of electrical input **610**. Control circuitry **620**, along with electrical input **610**, may therefore be used to monitor and control the temperature of TSU **100**. As a result, the TSU **100** may be heated to and maintained at a desired temperature.

[**0046**] Moreover, valve **632** may be coupled to piping (not shown) that bypasses TSU **100** and feeds into turbine **641** along with the output from TSU **100**. By controlling the portion of the total compressed air flow through the TSU, the ratio of heated to non-heated air provided to turbine **641** may be modified, thereby providing another means for controlling the temperature of the air being supplied to the turbine.

[**0047**] Another advantage of utilizing TSU **100** is that larger pressure tanks are not required as is the case with compressed air storage systems that do not utilize thermal storage units or combustion systems.

[**0048**] The present invention was presented in the context of industrial backup utility power. Alternatively, the present invention may be used in any application associated with generating power, such as in thermal and solar electric plants. Furthermore, the present invention may be used in any other application where thermal storage, fluid heating or heated fluid delivery may be desirable.

[**0049**] The above described embodiments of the present invention are presented for purposes of illustration and not of limitation, and the present invention is limited only by the claims which follow.

**1**. A thermal storage unit having a longitudinal axis, said unit comprising:

an annular flow channel disposed about an axis parallel to the longitudinal axis, said channel being formed between an inner cylindrical surface of a first member and an outer cylindrical surface of a second member, said outer cylindrical surface having a diameter smaller than said inner cylindrical surface;

a tubular inlet coupled to one end of said channel, said inlet for providing fluid in the gas phase to said channel; and

a tubular outlet coupled to the other end of said channel.

**2**. The thermal storage unit of claim 1, wherein each of said first and second members comprises thermal storage material.

**3**. The thermal storage unit of claim 2, wherein said thermal storage material comprises a solid mass.

**4**. The thermal storage unit of claim 3, wherein said solid mass is iron.

**5**. The thermal storage unit of claim 3, wherein said solid mass is aluminum.

**6**. The thermal storage unit of claim 3, wherein said solid mass is steel.

**7**. The thermal storage unit of claim 1 further comprising at least one heat source for heating said members.

**8**. The thermal storage unit of claim 7, wherein said at least one heat source comprises an external radiant heater.

**9**. The thermal storage unit of claim 7, wherein said at least one heat source comprises an internal radiant heater.

**10**. The thermal storage unit of claim 7, wherein said at least one heat source comprises a resistive heater.

**11**. The thermal storage unit of claim 7, wherein said at least one heat source comprises induction heating circuitry for causing current to circulate through said first and second members, whereby the circulating current heats said members.

**12**. The thermal storage unit of claim 7, wherein said at least one heat source is coupled to control circuitry, said control circuitry for controlling said at least one heat source to maintain said unit at a predetermined temperature.

**13**. The thermal storage unit of claim 1, wherein said axis parallel to said longitudinal axis comprises said longitudinal axis.

**14**. The thermal storage unit of claim 1, wherein said annular flow channel is a first annular flow channel, said axis parallel to said longitudinal axis is a first axis, said inner cylindrical surface of said first member is a first inner cylindrical surface, said thermal storage unit further comprising a second annular flow channel disposed about a second axis parallel to said longitudinal axis, said second channel being formed between a second inner cylindrical surface of said first member and an outer cylindrical surface of a third member, said outer cylindrical surface of said third member having a diameter smaller than said second inner cylindrical surface.

**15**. The thermal storage unit of claim 14, wherein said diameters of said outer cylindrical surfaces of said second and third members are substantially equal. The thermal storage unit of claim 14, wherein said first and second inner cylindrical surfaces have diameters that are substantially equal.

**16**. The thermal storage unit of claim 14, wherein said first and second inner cylindrical surfaces have diameters that are substantially equal.

**17**. A backup energy system comprising:

the thermal storage unit of claim 1 for heating a fluid in the gas phase;

a turbine coupled to said thermal storage unit for receiving said heated fluid, said received heated fluid driving said turbine; and

an electrical generator for providing power when said turbine is driven by said heated fluid.

**18**. The backup energy system of claim 17 further comprising a heating system for heating said thermal storage unit.

**19**. The backup energy system of claim 18 further comprising control circuitry coupled to said heating system and said thermal storage unit, said control circuitry for controlling said heating system to maintain said thermal storage unit at a predetermined temperature.

**20**. The backup energy system of claim 17, wherein said fluid is compressed air, said backup energy system further comprising a compressed air system to provide said compressed air to said thermal storage unit.

**21**. The backup energy system of claim 20, wherein said compressed air system is a storage tank that contains said compressed air.

**22**. The backup energy system of claim 17 further comprising a bypass valve coupled to said thermal storage unit, said bypass valve for controlling a portion of said fluid provided to said thermal storage unit.

**23-41**. (canceled)

**42**. A thermal storage unit having a longitudinal axis, said unit comprising:

a first annular flow channel disposed about a first axis parallel to said longitudinal axis, said first channel being formed between a first inner cylindrical surface of a first member and an outer cylindrical surface of a second member, said outer cylindrical surface of said second member having a diameter smaller than said first inner cylindrical surface; and

a second annular flow channel disposed about a second axis parallel to said longitudinal axis, said second channel being formed between a second inner cylindrical surface of said first member and an outer cylindrical surface of a third member, said outer cylindrical surface of said third member having a diameter smaller than said second inner cylindrical surface, wherein each of said first, second and third members comprises thermal storage material consisting of a solid mass.

**43**. The thermal storage unit of claim 42 further comprising:

a tubular inlet coupled to one end of said first and second channel, said inlet for providing fluid to said channel; and

a tubular outlet coupled to the other end of said first and second channel.

**44-45**. (canceled)

**46**. The thermal storage unit of claim 42, wherein said solid mass is iron.

**47**. The thermal storage unit of claim 42, wherein said solid mass is aluminum.

**48**. The thermal storage unit of claim 42, wherein said solid mass is steel.

**49**. The thermal storage unit of claim 42 further comprising at least one heat source for heating said members.

**50**. The thermal storage unit of claim 49, wherein said at least one heat source comprises an external radiant heater.

**51**. The thermal storage unit of claim 49, wherein said at least one heat source comprises an internal radiant heater.

**52**. The thermal storage unit of claim 49, wherein said at least one heat source comprises a resistive heater.

**53**. The thermal storage unit of claim 49, wherein said at least one heat source comprises induction heating circuitry for causing current to circulate through said first, second and third members, whereby the circulating currents heat said members.

**54**. The thermal storage unit of claim 49, wherein said at least one heat source is coupled to control circuitry, said control circuitry for controlling said at least one heat source in order to maintain said unit at a predetermined temperature.

**55**. The thermal storage unit of claim 42, wherein the diameters of said outer cylindrical surfaces of said second and third members are substantially equal in length.

**56**. The thermal storage unit of claim 42, wherein said first and second inner cylindrical surfaces have diameters that are substantially equal in length.

**57**. A backup energy system comprising:

the thermal storage unit of claim 42 for heating a fluid;

a turbine coupled to said thermal storage unit for receiving said heated fluid, said received heated fluid driving said turbine; and

an electrical generator for providing power when said turbine is driven by said heated fluid.

**58**. The backup energy system of claim 57 further comprising a heating system for heating said thermal storage unit.

**59**. The backup energy system of claim 58 further comprising control circuitry coupled to said heating system and said thermal storage unit, said control circuitry for controlling said heating system in order to maintain said thermal storage unit at a predetermined temperature.

**60**. The backup energy system of claim 57, wherein said fluid is compressed air, said backup energy system further comprising a compressed air system to provide said compressed air to said thermal storage unit.

**61**. The backup energy system of claim 60, wherein said compressed air system is a storage tank that contains said compressed air.

**62**. The backup energy system of claim 57 further comprising a bypass valve coupled to said thermal storage unit, said bypass valve for controlling a portion of said fluid provided to said thermal storage unit.

**63**. A thermal storage unit, having a longitudinal axis, that heats fluid flowing through said unit, comprising:

a first member comprising thermal storage material consisting of a solid mass and having an outer diameter;

a second member comprising thermal storage material consisting of a solid mass and having an inner diameter that is larger than said outer diameter;

an annular flow channel disposed about said axis and formed between said first and second members, wherein said first member is positioned within said second member;

an inlet coupled to one end of said channel that provides fluid to said channel;

an outlet coupled to the other end of said channel; and

at least one heat source that heats said first and second members.

**64**. A thermal storage unit, having a longitudinal axis, that heats fluid flowing through said unit, comprising:

a plurality of inner members each comprising thermal storage material consisting of a solid mass and having an outer diameter;

an outer member comprising thermal storage material consisting of a solid mass and having a plurality of through-holes bored therethrough, each said through-hole having an axis substantially parallel to said longitudinal axis, and wherein each said through-hole has a through-hole diameter that is larger than said outer diameter;

a plurality of annular flow channels disposed about each said through-hole axis, each said channel being formed between one of said plurality of inner members and one of said plurality of through-holes, wherein said each said inner member is positioned within said outer member;

an inlet coupled to one end of said channels that provides fluid to said channels;

an outlet coupled to the other end of said channels; and

at least one heat source that heats said plurality of inner members and said outer member.

**65**. A method for using a thermal storage unit in a backup power delivery system that uses fluid to provide electrical power, the method comprising:

preheating first and second members of said unit to a predetermined temperature;

providing fluid in the gas phase to said unit in the event of failure of a primary power source;

heating said fluid as said fluid passes through an annular channel that is formed between said first and second members; and

using said heated fluid to drive a turbine, which drives an electrical generator to provide electrical power.

**66**. The method of claim 65 further comprising controlling application of heat to said first and second members to maintain said thermal storage unit at a predetermined temperature.

**67**. A thermal storage unit having a longitudinal axis, said unit comprising:

an annular flow channel disposed about an axis parallel to the longitudinal axis, said channel being formed between an inner cylindrical surface of a first member and an outer cylindrical surface of a second member, said outer cylindrical surface having a diameter smaller than said inner cylindrical surface, said first member comprising thermal storage material consisting of a solid mass;

a tubular inlet coupled to one end of said channel, said inlet for providing fluid to said channel; and

a tubular outlet coupled to the other end of said channel.

**68**. The thermal storage unit of claim 67 further comprising at least one heat source for heating said first member.

**69**. The thermal storage unit of claim 68, wherein said heat source also heats said second member.

**70**. The thermal storage unit of claim 67, wherein said solid mass includes a material that is selected from the group consisting of iron, steel, aluminum and any alloys thereof.

**71**. A method for using a thermal storage unit in a backup power delivery system that uses fluid to provide electrical power, the method comprising:

preheating first and second members of said unit to a predetermined temperature wherein each member comprises thermal storage material consisting of a solid mass;

providing fluid to said unit in the event of failure of a primary power source;

heating said fluid as said fluid passes through an annular channel that is formed between said first and second members; and

using said heated fluid to drive a turbine, which drives an electrical generator to provide electrical power.

**72**. The method of claim 71 further comprising controlling application of heat to said first and second members to maintain said thermal storage unit at a predetermined temperature.

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