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(54) SYSTEM AND APPARATUS FOR CONDENSATION OF LIQUID FROM GAS AND METHOD OF COLLECTION OF LIQUID

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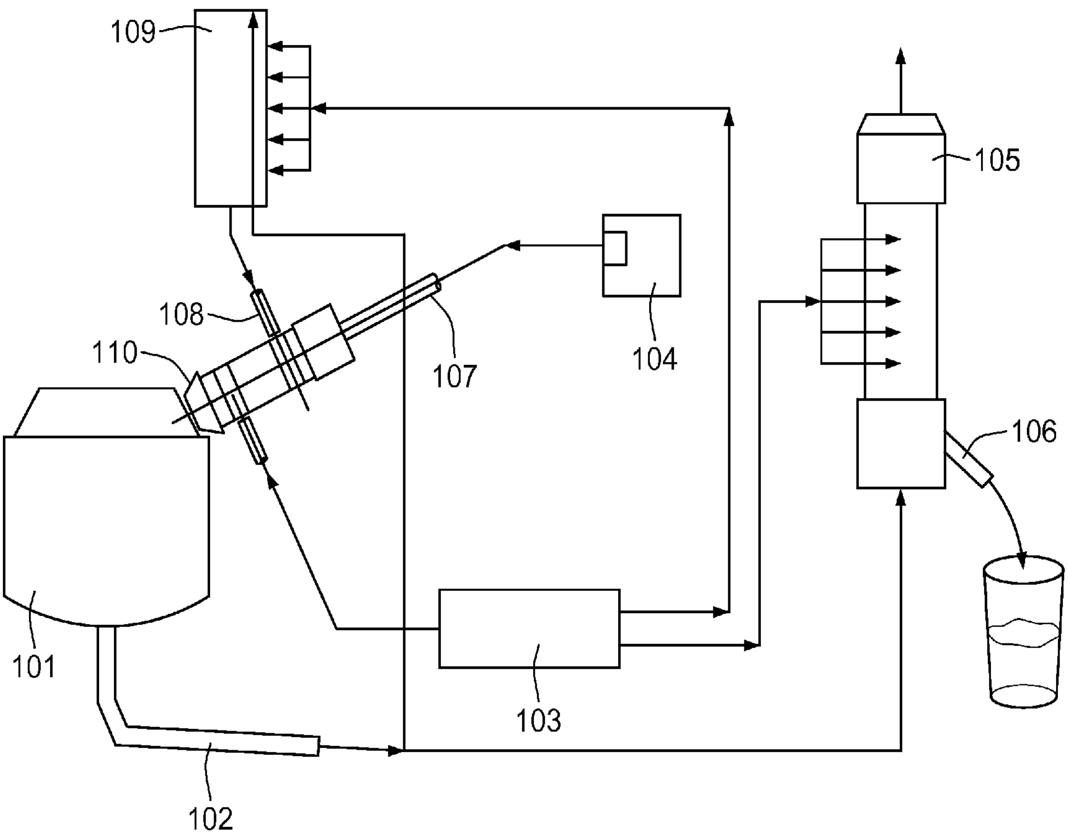
(52) **U.S. Cl.** .... **123/25 R**; 62/401; 62/90

(57) **ABSTRACT**

The present disclosure generally relates to an apparatus for the condensation of a liquid suspended in a gas, and more specifically, to an apparatus for the condensation of water from air with a geometry designed to emphasize adiabatic condensation of water using either the Joule-Thompson effect or the Ranque-Hilsch vortex tube effect or a combination of the two. Several embodiments are disclosed and include the use of a Livshits-Teichner generator to extract water and unburned hydrocarbons from exhaust of combustion engines, to collect potable water from exhaust of combustion engines, to use the vortex generation as an improved heat process mechanism, to mix gases and liquid fuel efficiently, and an improved Livshits-Teichner generator with baffles and external condensation.



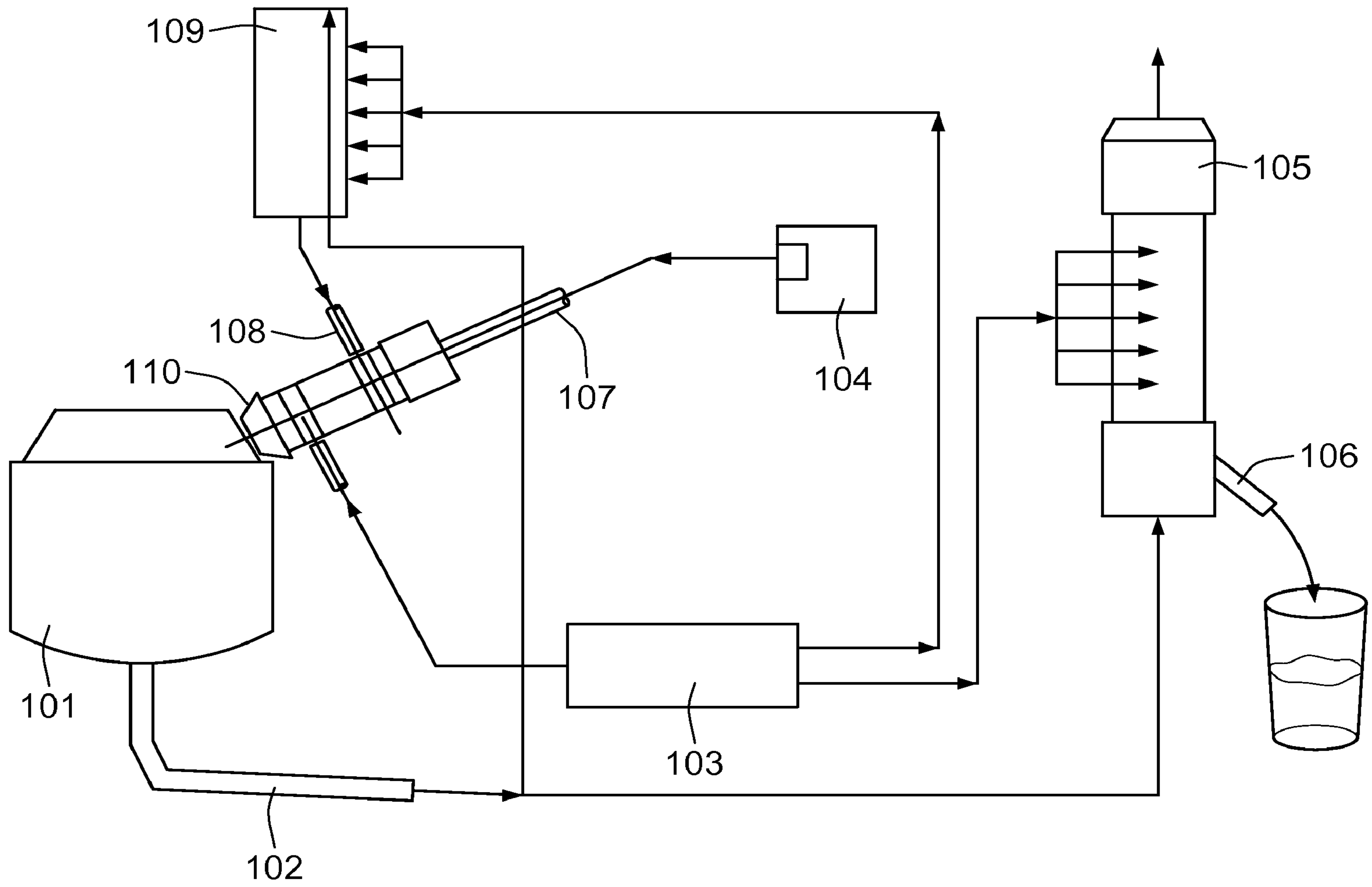


FIG. 1

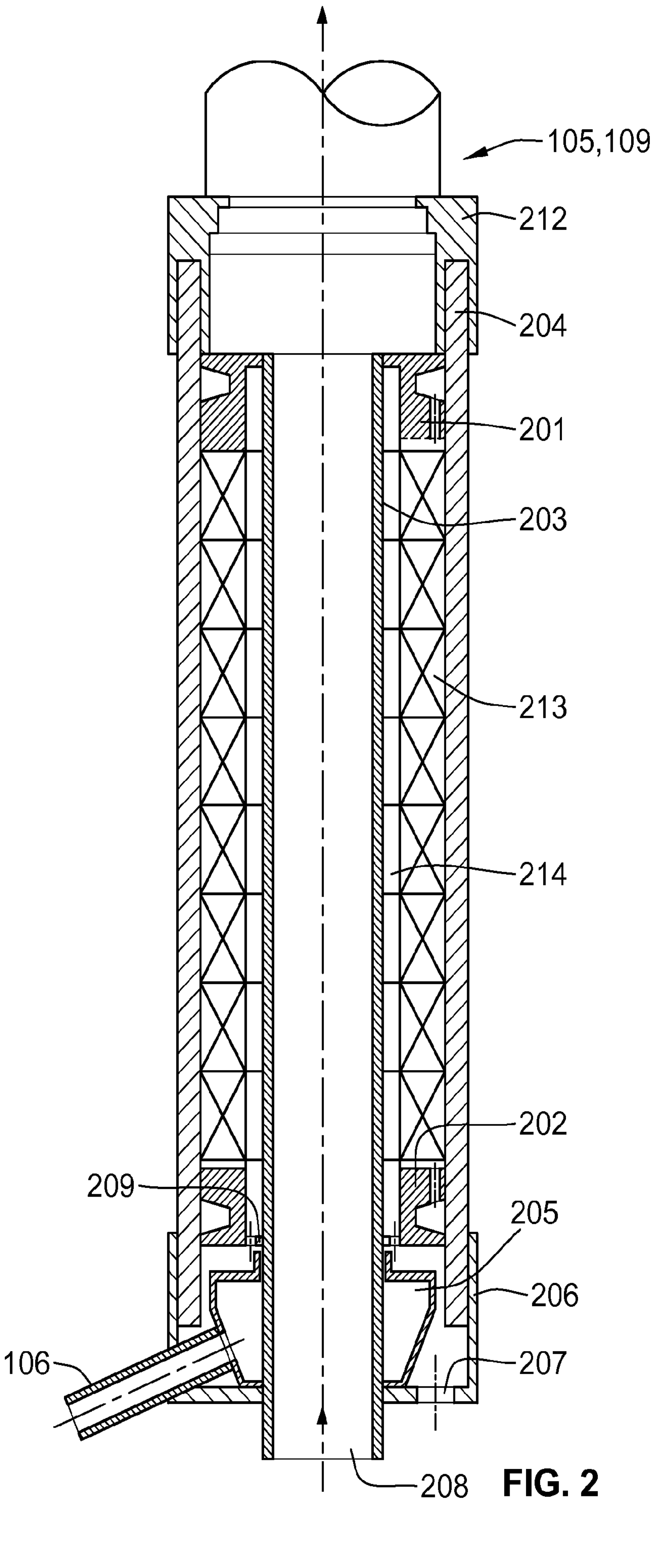


FIG. 2

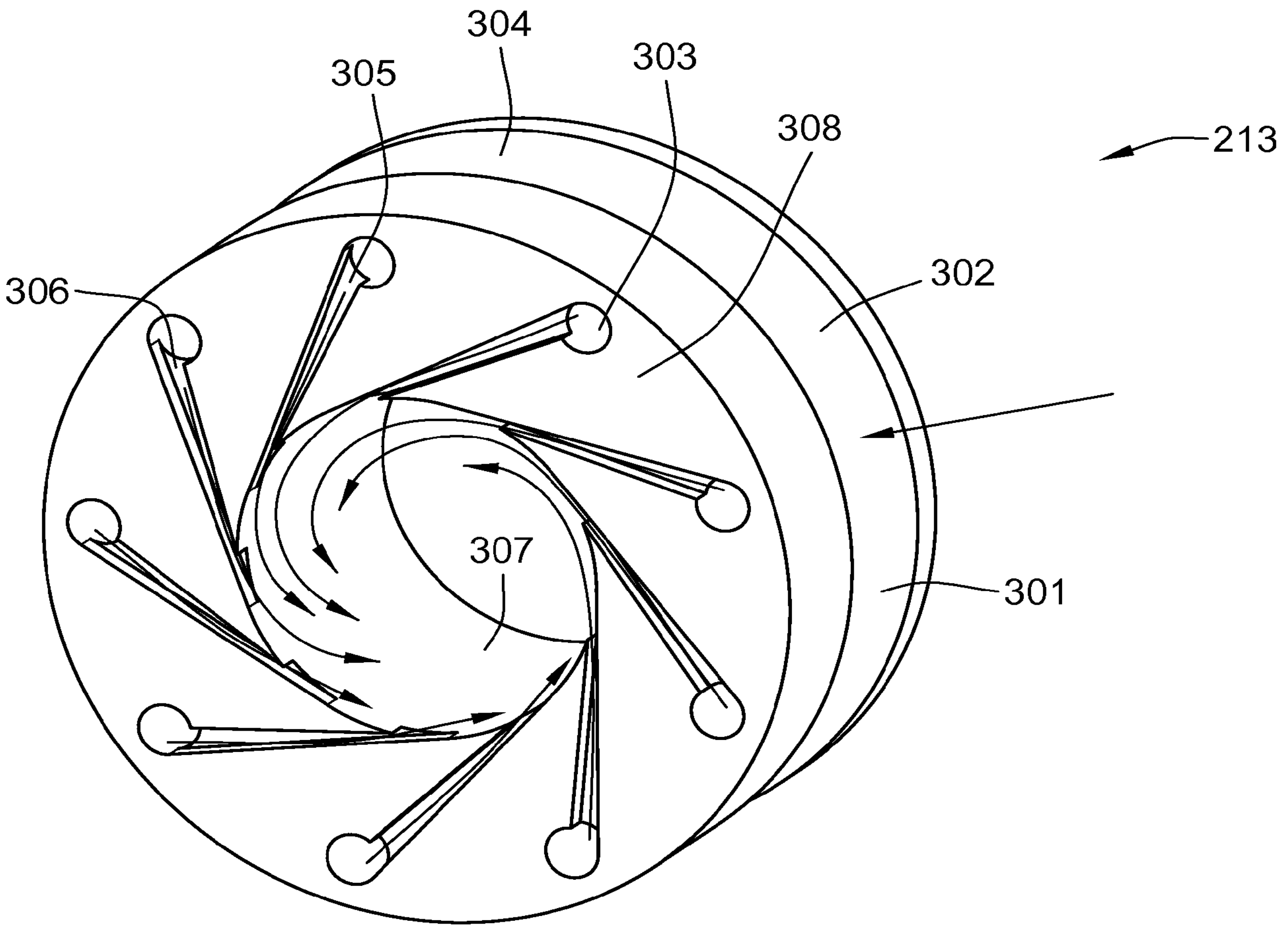


FIG. 3

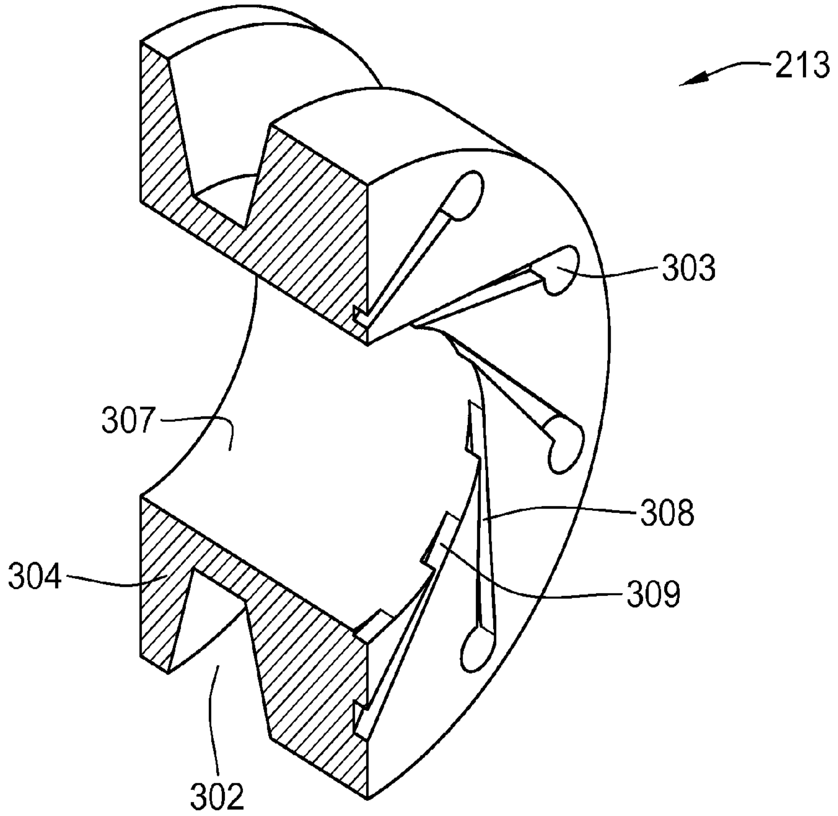


FIG. 4

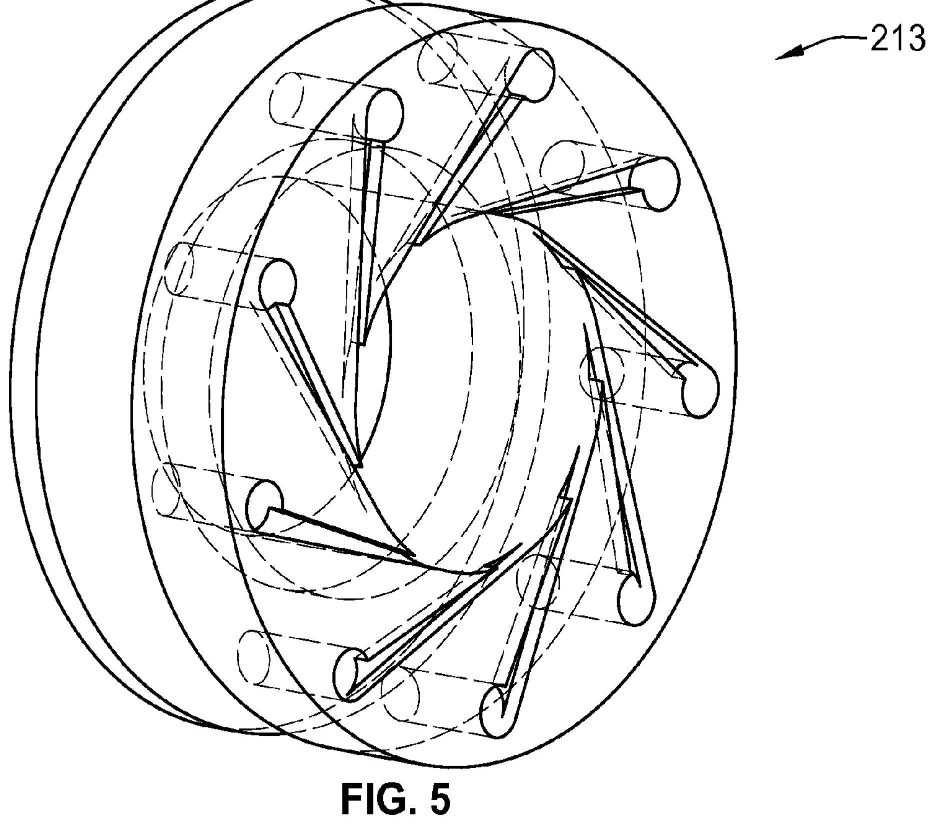


FIG. 5

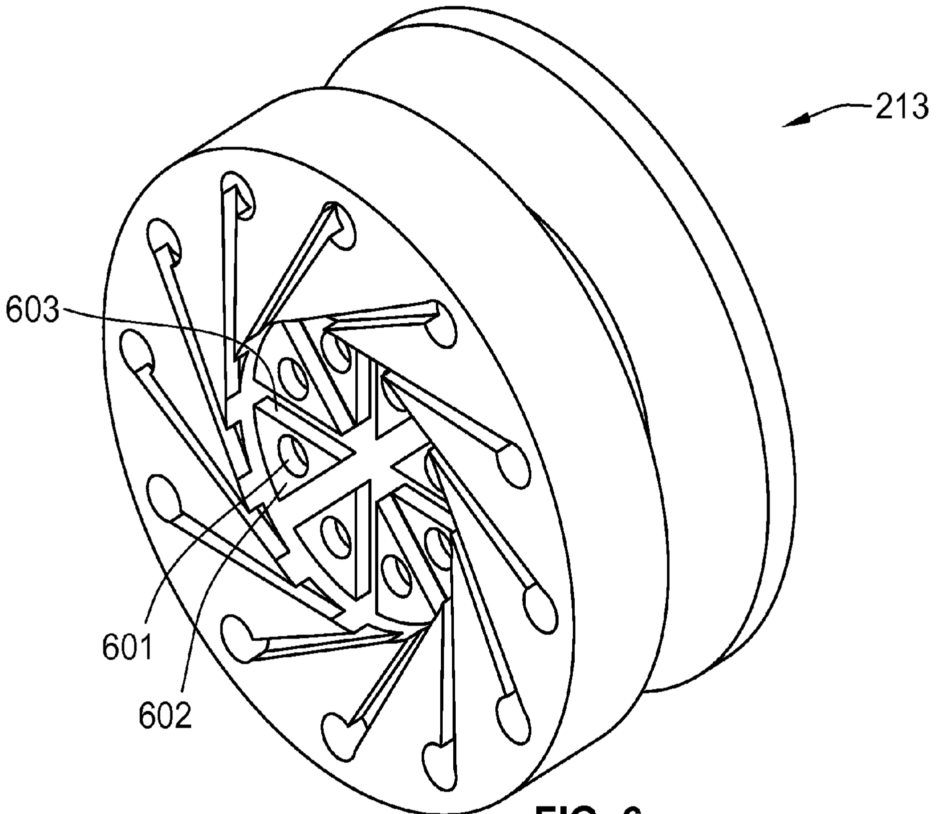


FIG. 6

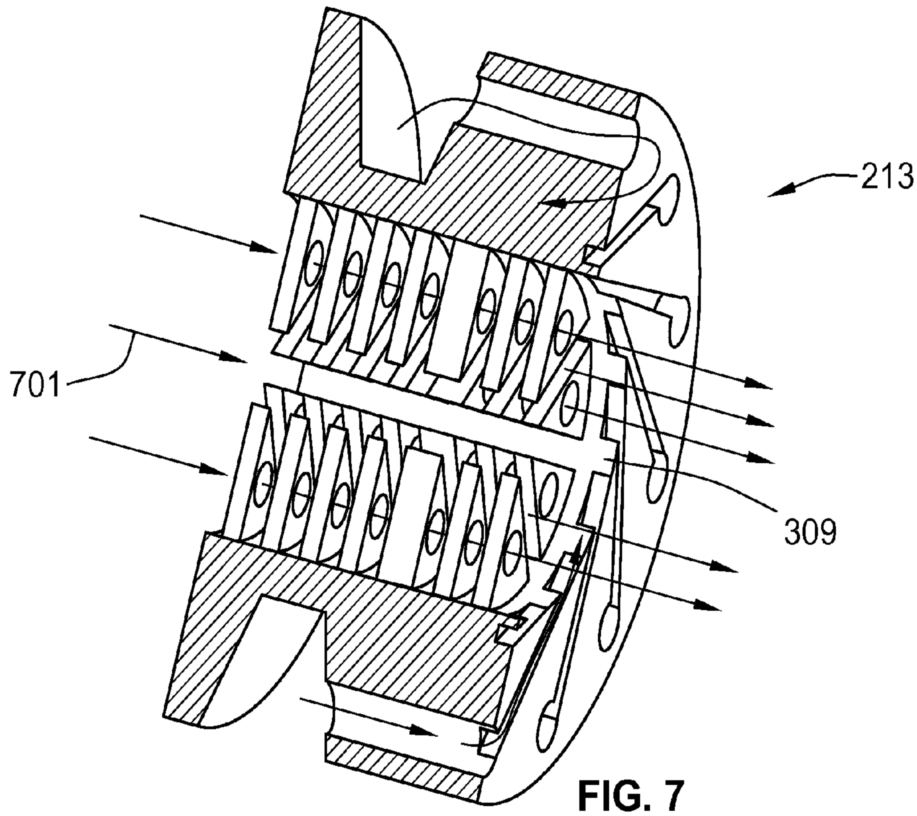


FIG. 7

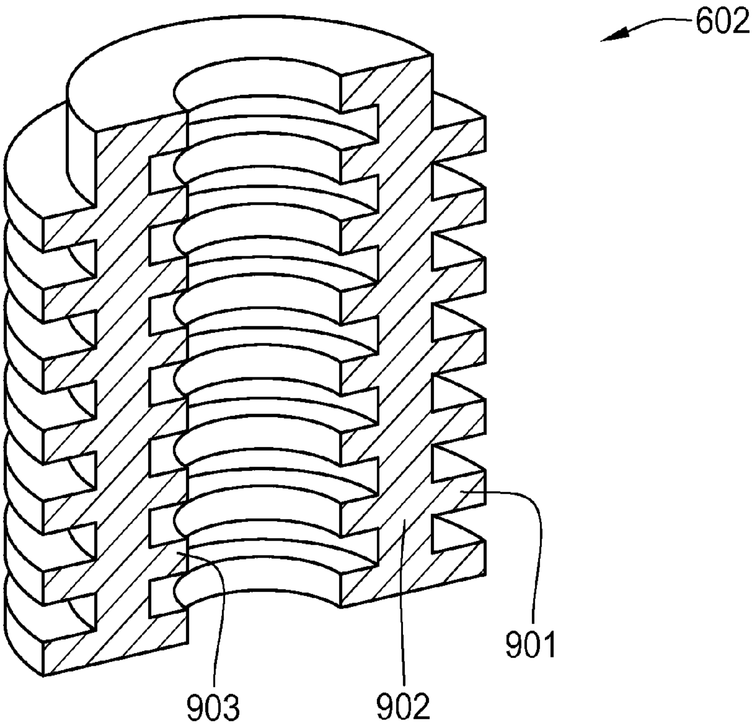


FIG. 8

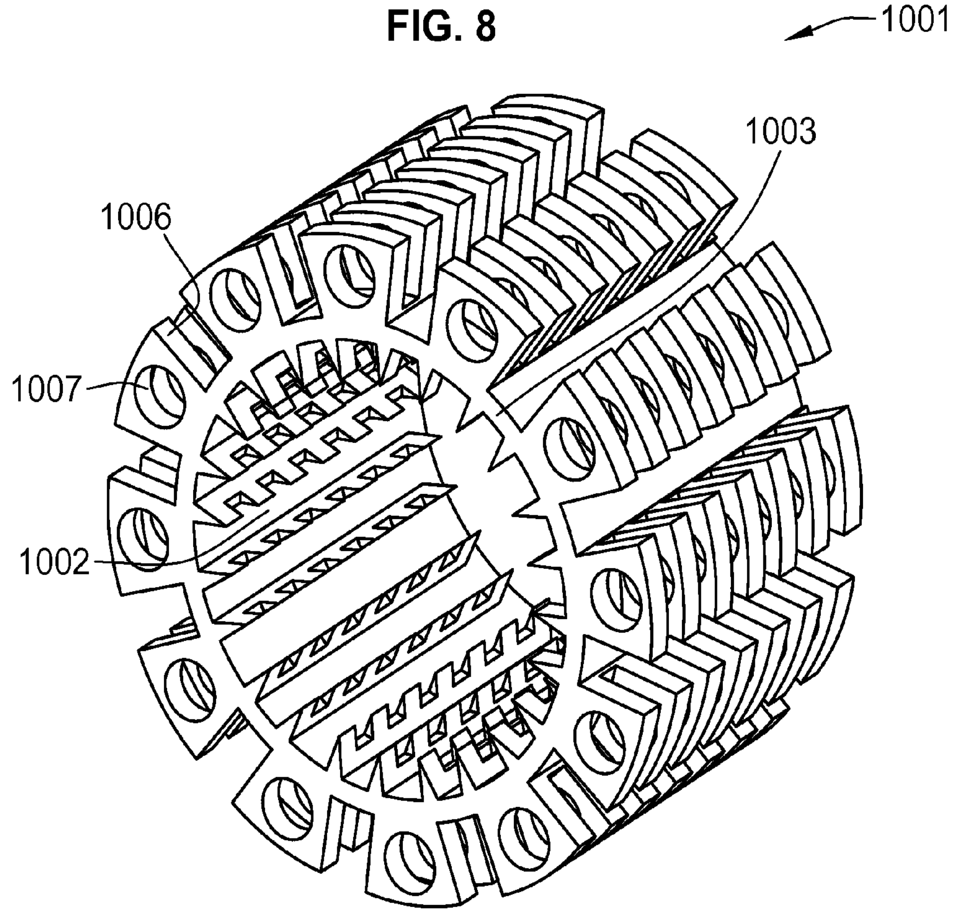


FIG. 9

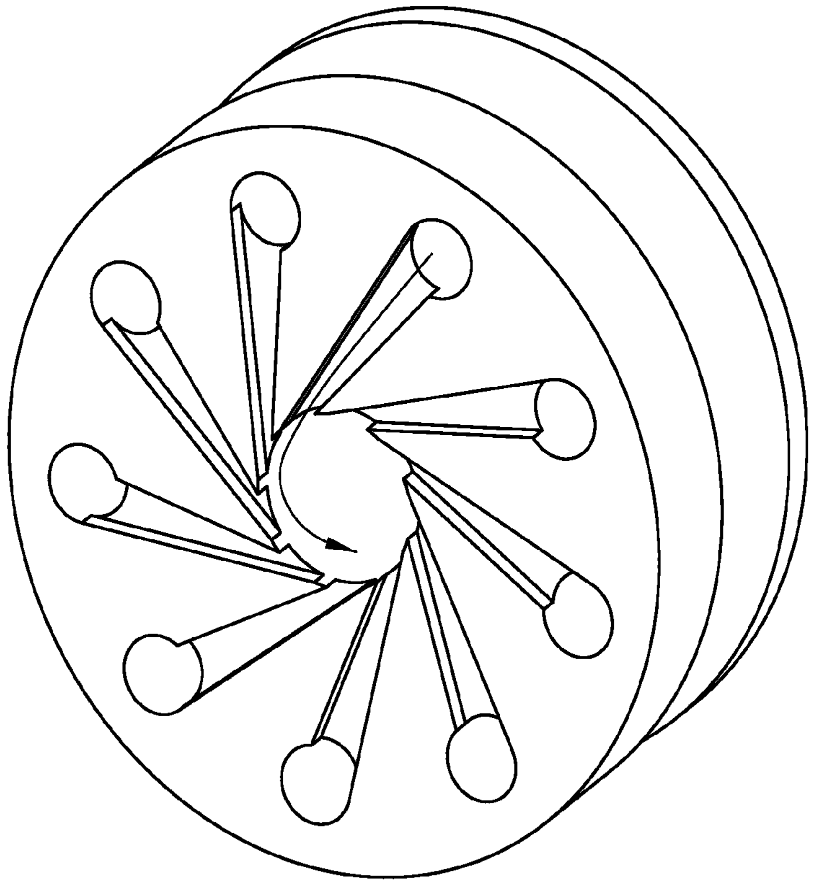


FIG. 10

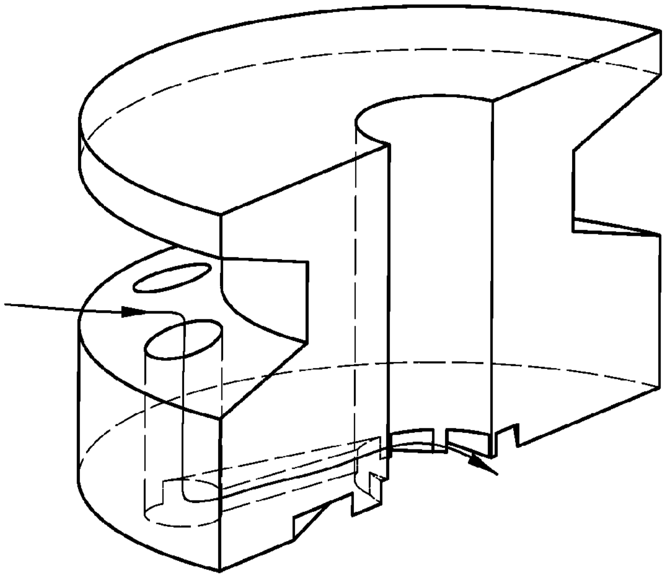


FIG. 11

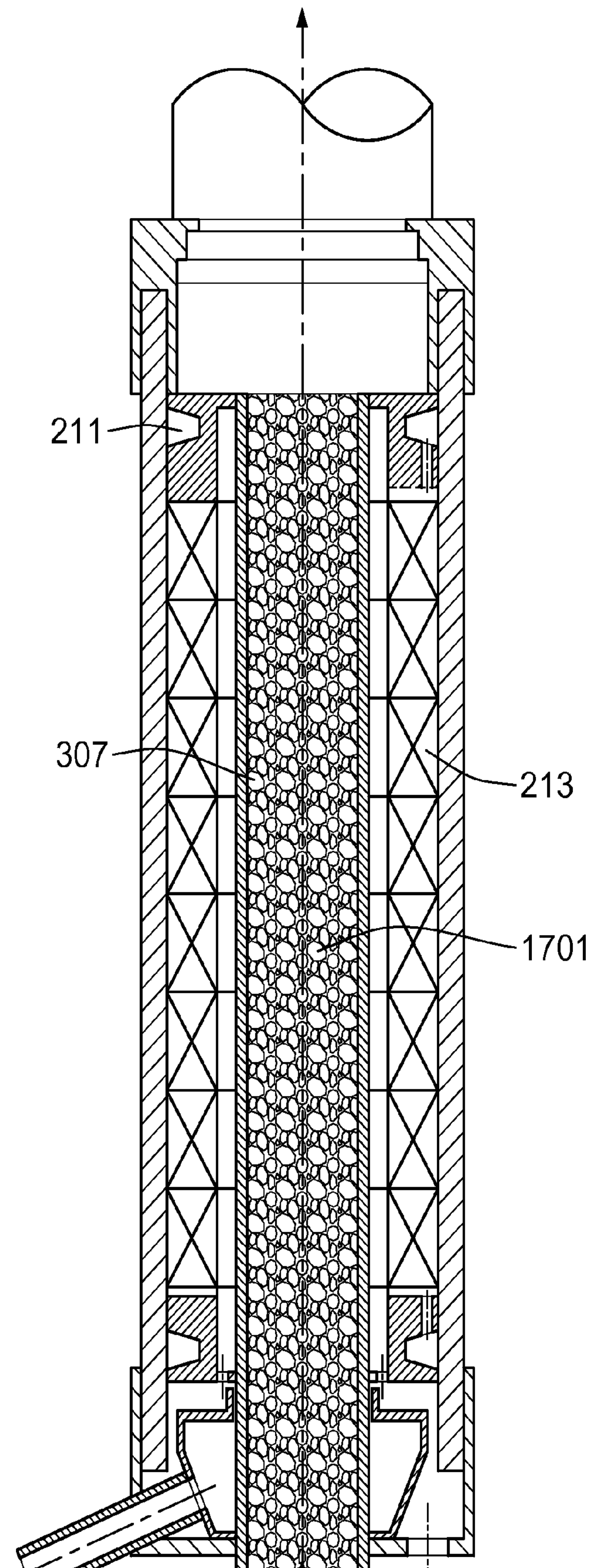


FIG. 12

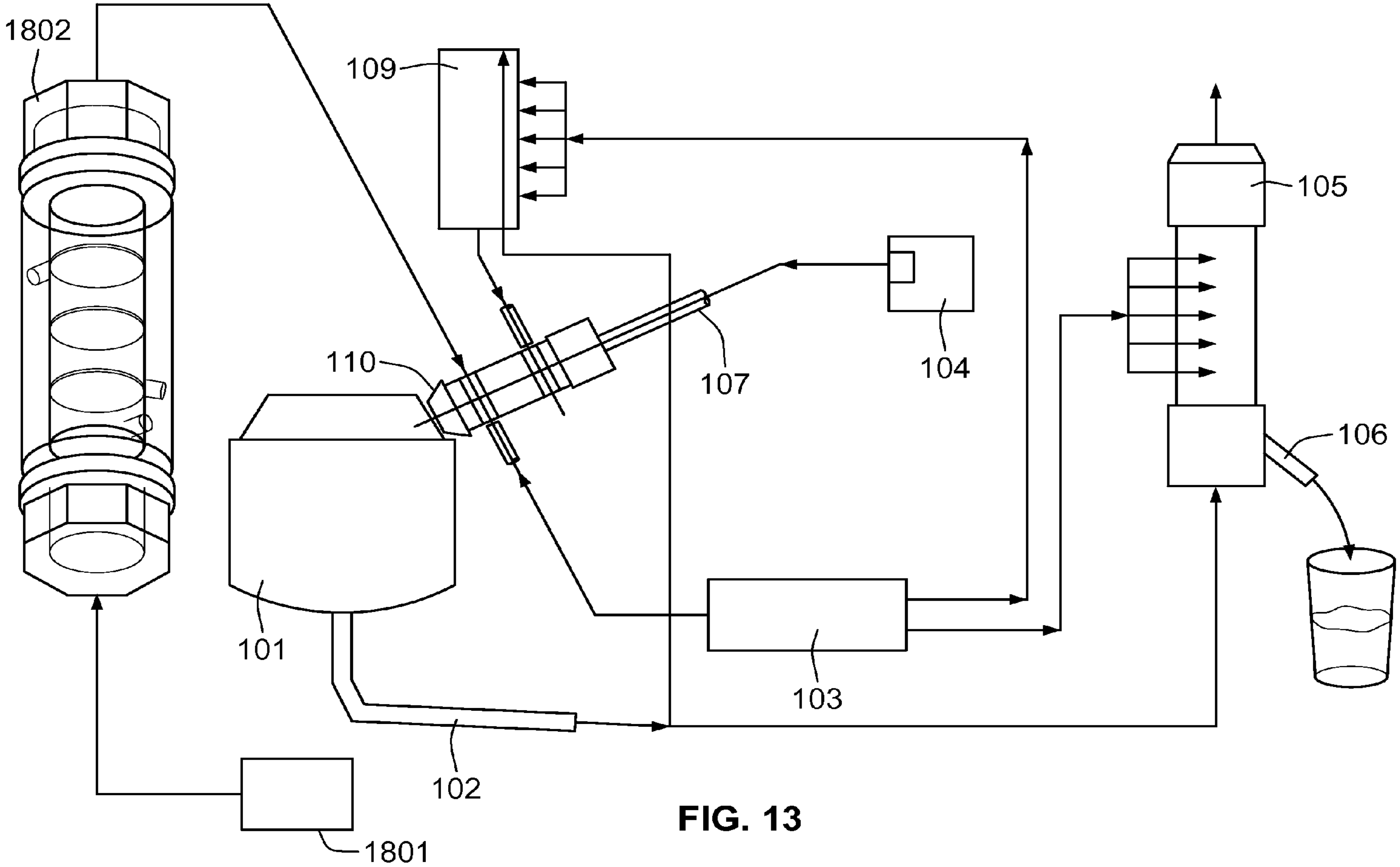


FIG. 13

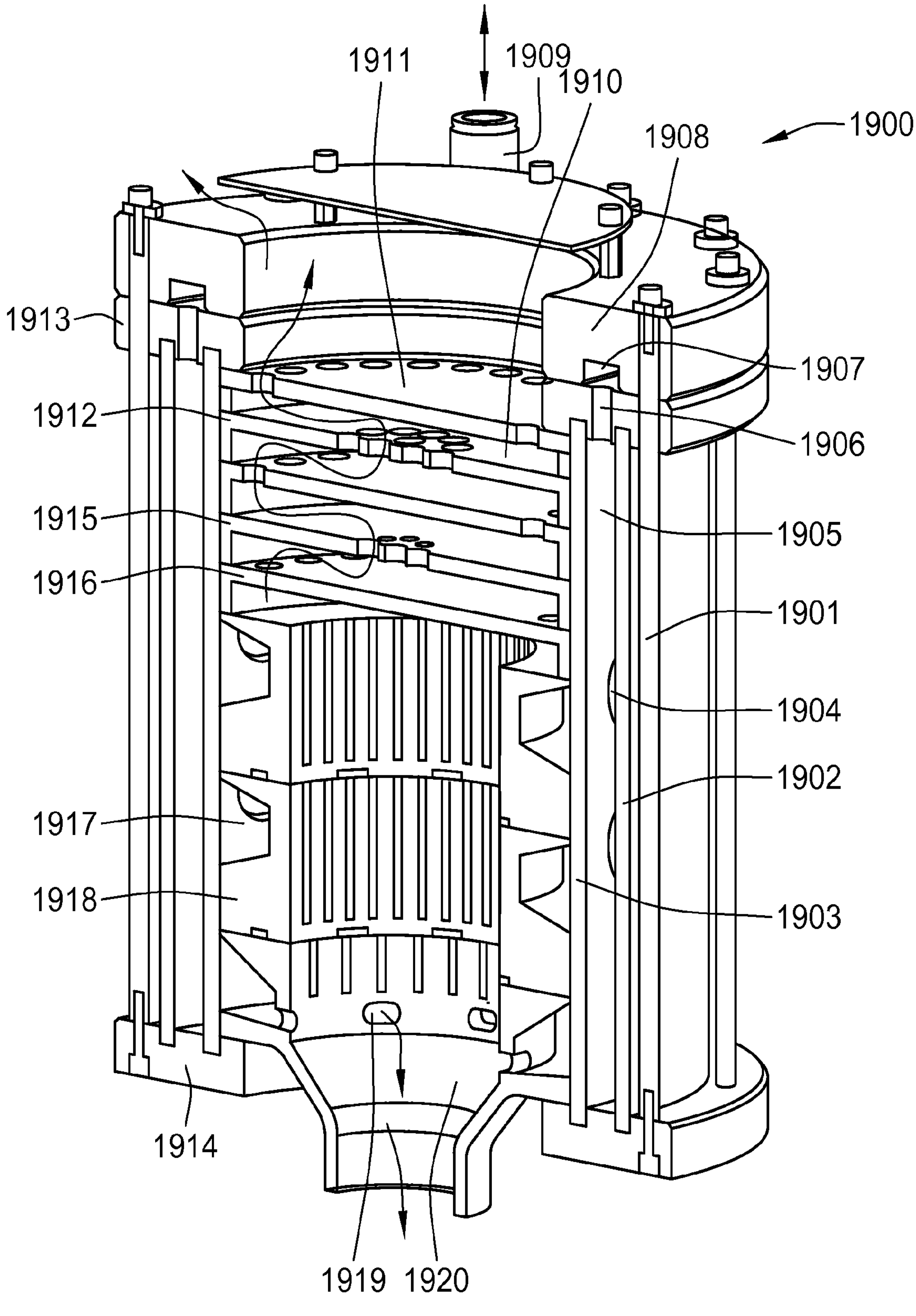


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FIG. 14

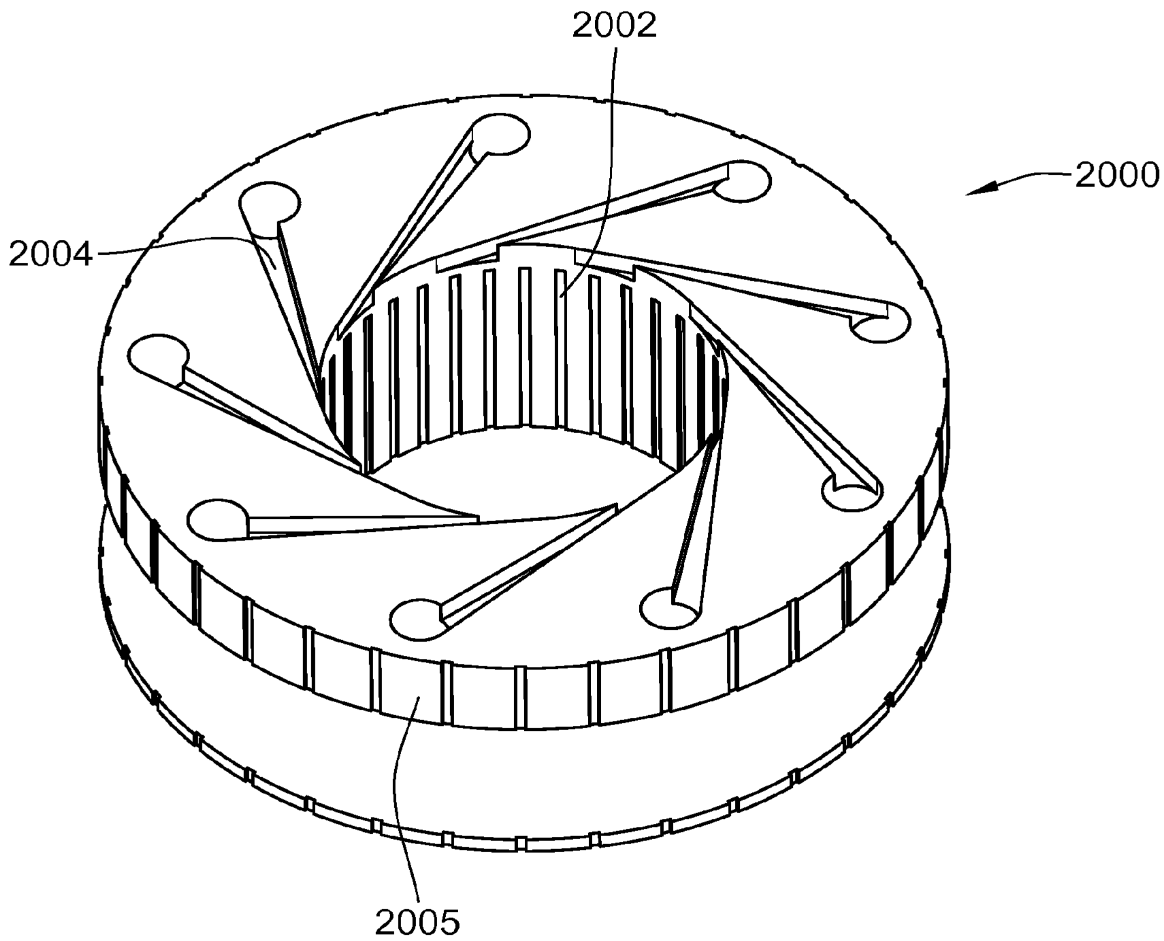

FIG. 18

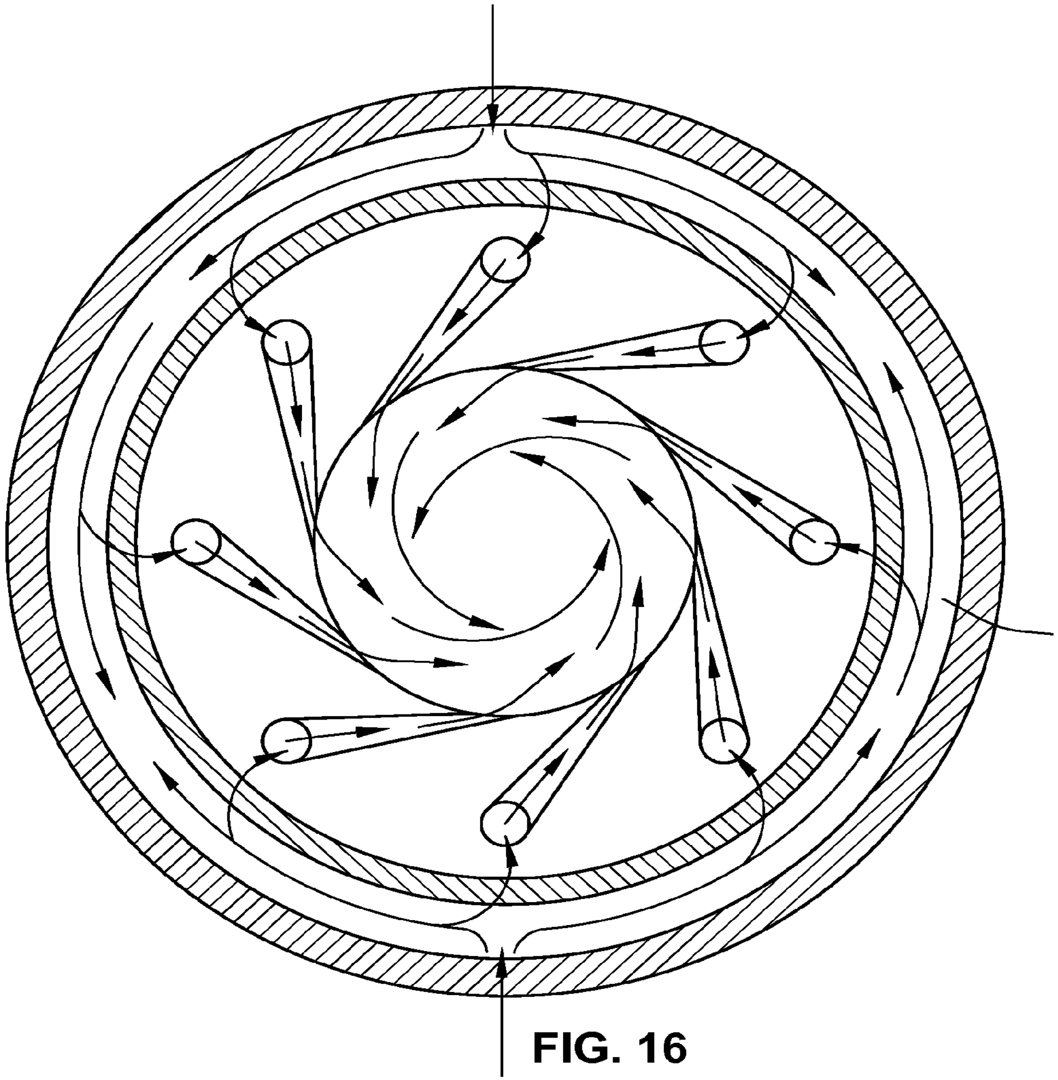

FIG. 16

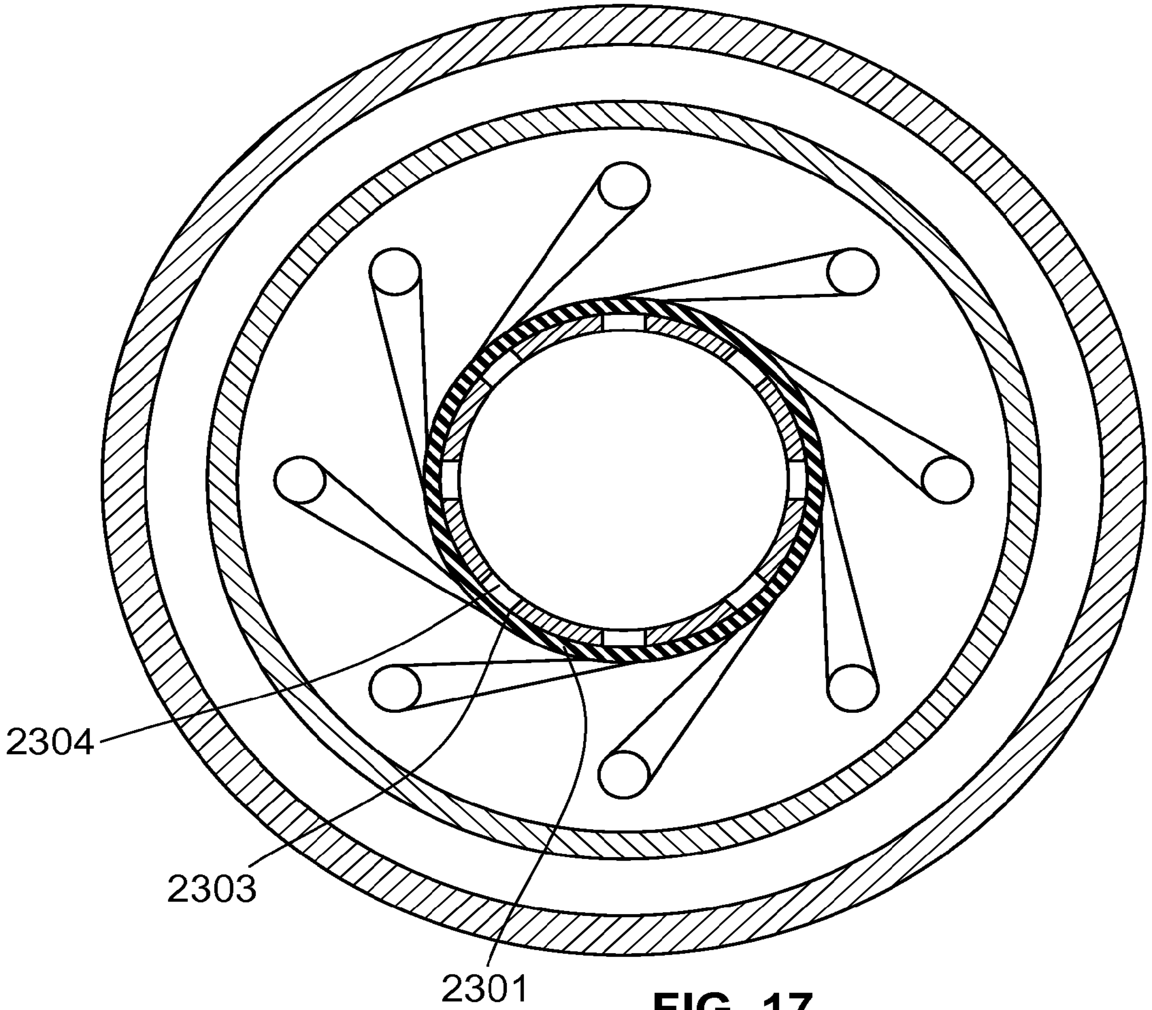

FIG. 17

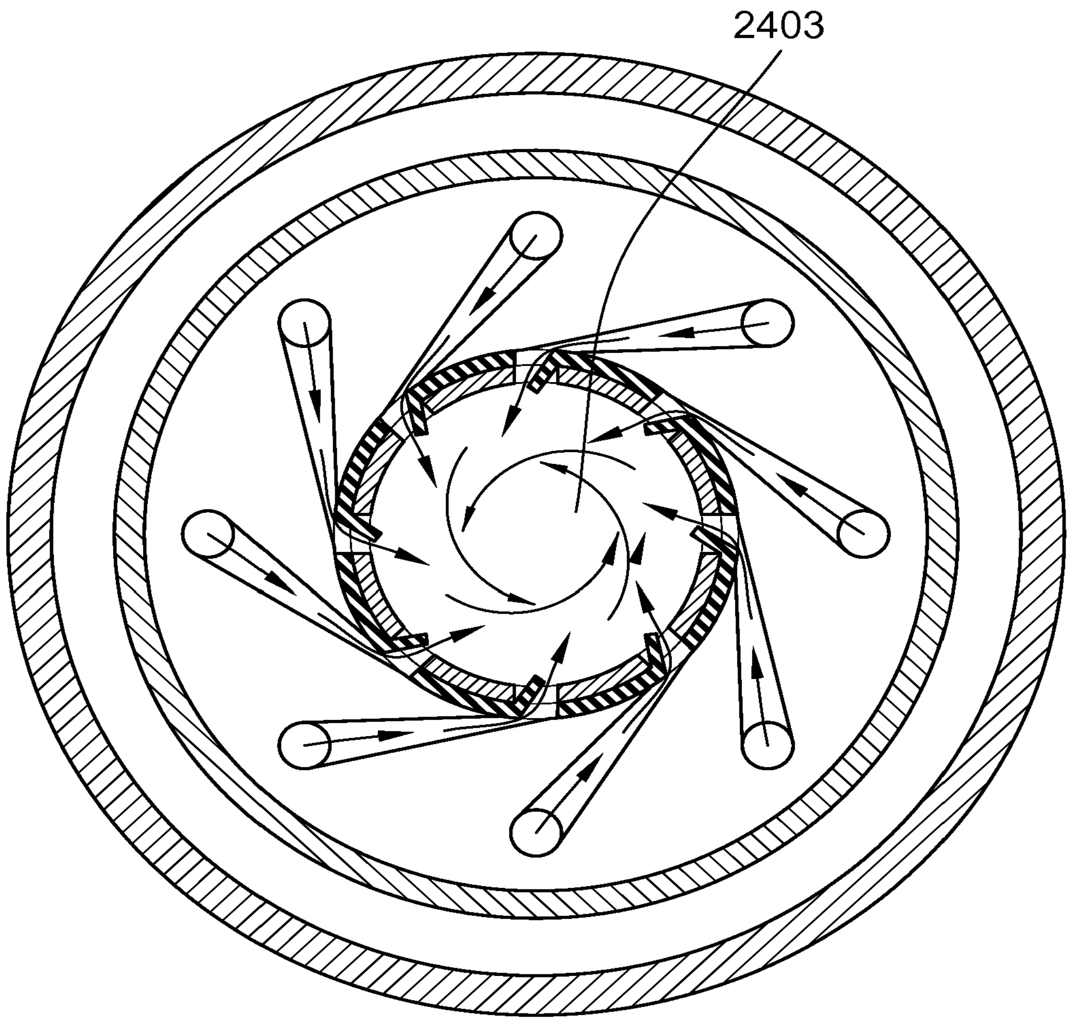

FIG. 18

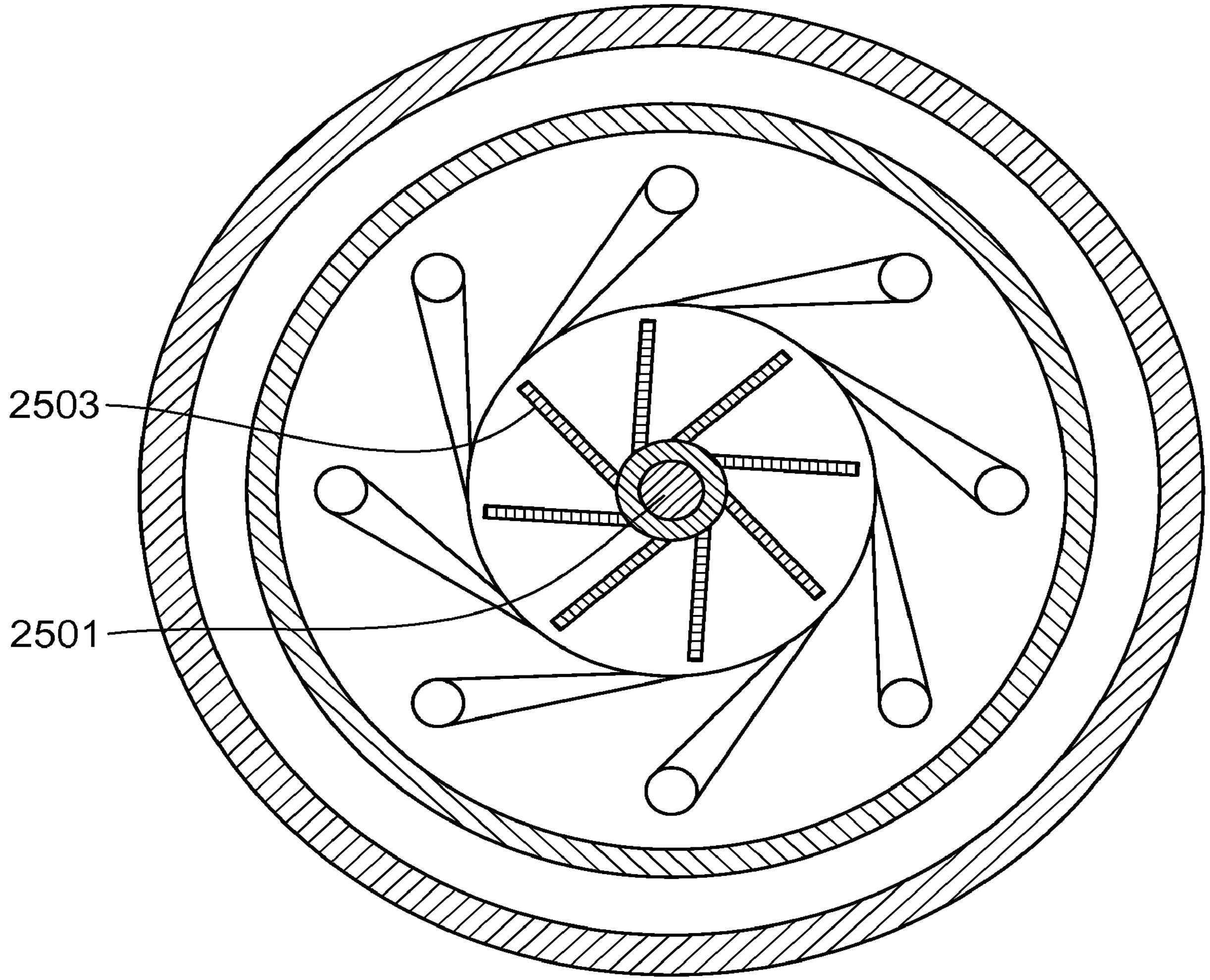

FIG. 19

SYSTEM AND APPARATUS FOR CONDENSATION OF LIQUID FROM GAS AND METHOD OF COLLECTION OF LIQUID

FIELD OF THE DISCLOSURE

[0001] The present disclosure generally relates to an apparatus and system for condensation and collection of a liquid suspended in a gas, and more specifically, to an apparatus for condensation of water from air with a geometry designed to emphasize adiabatic condensation of water using either the Joule-Thompson effect or the Ranque-Hilsch vortex tube effect or a combination of the two.

BACKGROUND

[0002] Liquids may be in stable equilibrium within a gas. For example, water vapor, the gas phase of water under normal atmospheric conditions, is found in air in a relative humidity level ranging from a couple percentiles to saturation. This water vapor is generally evaporated from a liquid through the absorption of kinetic energy. When such water vapor leaves a volume of water, the rest of the water is cooled via a process called evaporative cooling. Humans sweat perspiration at the surface of their skin to cool the body.

[0003] As water vapor enters the air, relative humidity increases. Humidity is generally expressed in specific humidity or percentage of relative humidity. The temperatures of the atmosphere and the water surface determine the equilibrium vapor pressure. At 100% of relative humidity, the partial pressure of the water vapor is equal to the equilibrium vapor pressure. This effect is also called complete saturation. At a saturated atmospheric atmosphere at a temperature of 30° C., 30 grams of water can be stored in one cubic meter of air (0.03 ounce per cubic foot).

[0004] Since the molecular weight of water is 18.02 g/mol and the molecular weight of air is approximately 28.57 g/mol at standard temperature and pressure (STP), a mixture of water vapor and air has a molar volume of 22.414 liter/mol at STP. The saturation fraction of water in air at sea level increases from approximately 0.7% at 0° C., to 1.7% at 20° C., to 3% at 30° C. The maximum partial pressure (saturation pressure) of water vapor in air varies with temperature of the air and the water vapor mixture. For a given quantity of water vapor in air, as the air is cooled past the saturation pressure, water is extracted via condensation from the air. This condensation occurs in proximity of the gas on any surface capable of absorbing heat. A plurality of complex devices exist in the marketplace to extract liquids from gases, but these devices are bulky, require activation energy, and have moving parts. Devices and methods of extracting water vapor without activation energy or moving parts are needed. Water collected from condensation can also be blended into fuel in some types of combustion engines.

[0005] In thermodynamics, the Joule-Thomson effect, also known as the Joule-Kelvin effect or Kelvin-Joule effect, describes the temperature change of a gas or liquid when it is forced through a valve or a conduit while being insulated so that no heat is exchanged with its immediate environment. At room temperature, all gases except for hydrogen, helium, and neon cool upon expansion via the Joule-Thompson effect. An adiabatic (no heat exchanged) expansion of gas can be effected where a gas with a liquid phase at initial pressure P_1 flows into a region of lower pressure P_2 via a release mechanism under steady-state conditions and without a change in kinetic energy. During this process, enthalpy remains unchanged and causes cooling of the gas. This gas may in turn be warmed if placed in contact with a heat sink, which is also cooled in turn. As the gas cools and is placed in contact with a cold surface, condensation of the liquid fraction that reaches localized saturation occurs.

[0006] The Joule-Kelvin rate of change in temperature (T) with respect to a pressure P in a process at constant enthalpy H is the Joule-Thompson coefficient μ_{JT}. This coefficient is expressed in terms of a gas's volume (V), the heat capacity at constant pressure CP, and the coefficient of thermal expansion of a gas (α), which is expressed as the following equation:

$$\mu_{JT} = \left(\frac{\partial T}{\partial P}\right)_H = \frac{V}{C_P}(\alpha T - 1))$$

[0007] As the gas cools, the coefficient μ_{JT} remains positive as long as the partial derivative of the temperature (∂T) is negative as the partial derivative of the pressure (∂P) also remains negative due to a loss of pressure from P_1 to P_2. In a gas with a fixed quantity of water vapor, as the pressure drops as the positive Joule-Thompson coefficient between two successive areas in the flow of a gas is calculated. The conditions may exceed the saturation point and force local condensation. What is known in the art is the use of the Joule-Thomson effect to cool down a gas.

[0008] Another effect known to cool a stream of gas is the Ranque-Hilsch vortex tube. In a mechanical device, compressed gas can be separated into a hot and a cold stream using no moving parts under the Ranque-Hilsch vortex tube effect. Pressurized gas is injected tangentially into swirl chamber and accelerates to a high rate of rotation. Due to the conical nozzle at an end of the tube, only the outer shell of the compressed gas is allowed to escape at that end. The remainder of the gas is forced to return in an inner vortex of reduced diameter within the outer vortex. There is no commonly accepted theory for this effect, and there is debate as to which explanation is best or correct. What is usually agreed upon is that the air in a tube experiences mostly "solid body rotation," which simply means the rotation rate of angular velocity of the inner gas is the same as that of the outer gas. There are currently very few industrial applications of this effect. One of these rare applications includes using the vortex tube energy separation as a method to recover waste pressure energy from high and low pressure sources. See Sachim U. Nimbalkar, Dr. M. R. Mueller, "Utilizing waster Pressure in Industrial Systems." *Energy: Production, Distribution, and Conservation*," ASME-ATI 2006, Milan. What is known in the art is the use of the Ranque-Hilsch vortex tube effect to cool a gas.

[0009] What is needed is an apparatus and an associated method of use for the cooling of gas and an apparatus also adapted for the extraction and condensed liquid from the gas, along with a method of production of liquid such as water from a gas such as air where the Joule-Thompson effect and the Ranque-Hilsch vortex tube effect are used alternately or in combination.

SUMMARY

[0010] The present disclosure generally relates to an apparatus for the condensation of a liquid suspended in a gas, and more specifically, to an apparatus for the condensation of water from air with a geometry designed to emphasize adiabatic condensation of water using either the Joule-Thompson effect or the Ranque-Hilsch vortex tube effect or a combination of the two. Several embodiments are disclosed and include the use of a Livshits-Teichner generator to extract water and unburned hydrocarbons from exhaust of combustion engines, to collect potable water from exhaust of combustion engines, to use the vortex generation as an improved heat process mechanism, to mix gases and liquid fuel efficiently, and an improved Livshits-Teichner generator with baffles and external condensation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Certain embodiments are shown in the drawings. However, it is understood that the present disclosure is not limited to the arrangements and instrumentality shown in the attached drawings.

[0012] FIG. **1** is schematic plan of a thermodynamic process for the condensation of liquid from gas where water is extracted from a gas such as an hot exhaust gas from an internal combustion engine.

[0013] FIG. **2** is a cross-sectional view of a Livshits-Teichner generator as part of the thermodynamic process shown as FIG. **1** according to an embodiment of the present disclosure.

[0014] FIG. **3** is an isometric view of a Livshits vortex generator used for turbulent mixing and cooling of air as part of the Livshits-Teichner generator of FIG. **2** according to an embodiment of the present disclosure.

[0015] FIG. **4** is a half section of the Livshits vortex generator of FIG. **3**.

[0016] FIG. **5** is a transparent model of the Livshits vortex generator of FIG. **3**.

[0017] FIG. **6** is a end view of another Livshits vortex generator having a smaller internal cavity and a heat exchange structure according to another embodiment of the disclosure.

[0018] FIG. **7** is a half section of the Livshits vortex generator of FIG. **6**.

[0019] FIG. **8** is a half section of another type of heat exchange structure for placement within an internal cavity of a Livshits vortex generator according to another embodiment of the present disclosure.

[0020] FIG. **9** is another type of heat exchange structure for placement within an internal cavity of a Livshits vortex generator according to another embodiment of the present disclosure.

[0021] FIG. **10** is an isometric view of another embodiment of Livshits vortex generator used for turbulent mixing and cooling of air as part of the Livshits-Teichner generator of FIG. **2** where the tangential channels are of variable width according to an embodiment of the present disclosure.

[0022] FIG. **11** is a transparent version of the half section illustration of the Livshits vortex generator of FIG. **10**.

[0023] FIG. **12** is the cross-sectional view of the Livshits-Teichner generator of FIG. **2** where filtering material is located within the internal cavity.

[0024] FIG. **13** is the schematic plan of a thermodynamic process for the condensation of liquid from gas where water is extracted from a gas such as hot exhaust gas from an internal combustion engine of FIG. **1** where a device for the activation of a fuel mix is included as part of the process of the internal combustion engine.

[0025] FIG. **14** is another half isometric view of another Livshits-Teichner generator according to another embodiment of the present disclosure with kinetic energy brake disks used with several Livshits vortex generators and a water collection end.

[0026] FIG. **15** is another embodiment of the Livshits vortex generator according to FIG. **3** with partial internal channels and full external channels according to another embodiment of the present disclosure.

[0027] FIG. **16** is a plan view of the dynamic flow of gas in a Livshits vortex generator in a Livshits-Teichner generator and external pipe as shown in FIG. **14** according to another embodiment of the present disclosure.

[0028] FIG. **17** is the Livshits vortex generator of FIG. **14** with a diaphragm and a biasing element within the internal cavity of the Livshits vortex generator according to another embodiment of the present disclosure.

[0029] FIG. **18** is the Livshits vortex generator of FIG. **14** where the dynamic flow is indicated and the biasing element is shown in an open configuration.

[0030] FIG. **19** is the Livshits vortex generator of FIG. **14** where a turbine generator is placed within the internal cavity according to another embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0031] For the purposes of promoting and understanding the principles disclosed herein, reference is now made to the preferred embodiments illustrated in the drawings, and specific language is used to describe the same. It is nevertheless understood that no limitation of the scope of the invention is hereby intended. Such alterations and further modifications in the illustrated devices and such further applications of the principles disclosed and illustrated herein are contemplated as would normally occur to one skilled in the art to which this disclosure relates.

[0032] Obtaining liquid from gas, such as water from air or water from exhaust gases of vehicles, can be very desirable when water is not readily available. Water vapor is normally present in air even in extremely dry climates, such as deserts, or in heated exhaust gases of vehicles. Gases can be naturally pressurized or can be pressurized using a pump before they enter a process. In one embodiment, water is collected using a Livshits-Teichner generator **105**, **109** as seen in FIG. **2** made of a plurality of Livshits rings **213** to extract water from exhaust gas to blend back into fuel for specific combustion engines where a fraction of water is useful to the fuel mix. In another embodiment, water is collected using the Livshits-Teichner generator to extract potable water from a gas.

[0033] Because of the compact size of the Livshits ring **213**, and thus the compact size of the Livshits-Teichner generator **105**, **109**, the generators may be added to existing systems and processes to increase overall efficiency. Further, because no moving parts or external energy is needed aside from the pressure of input gas within the Livshits-Teichner generator **105**, **109**, no additional energy source is needed and the generators can be used in conjunction with existing engines, fuel pressure pumps, compressors, exhaust gas flow, or any device where liquid separation from a gas is contemplated. In yet another embodiment, condensation may also be used to capture small particles such as soot particles from an exhaust gas to return unburned oxides to the combustion chamber for improved efficiency of devices.

[0034] While no particular application for the Livshits-Teichner generator **105**, **109** is given, what is contemplated is the use of the generator in any stationary or nonstationary equipment, such as but not limited to a residential, commercial, industrial, or defensive application.

[0035] FIG. **1** shows a combustion cycle such as a diesel engine cycle where a tank **104** containing fuel such as diesel fuel is connected with a pump via a fuel pipeline **107** to a device for mixing and activations of a fuel mix **110**. The fuel mix device **110** is described with greater specificity in International Patent Application No. PCT/US2008/075366 filed on Sep. 5, 2008, and International Patent Application No. PCT/2008/075374 also filed on Sep. 5, 2008, where both applications are hereby fully incorporated herein by reference. The device **110** allows for the production of a mixture at an entry of a diesel engine **101** of an incompressible fluid, such as the diesel fuel from the tank **104** mixed with air from a compressor **103** and/or one or several auxiliary liquids such as water introduced at a connector **108** into the mixture.

[0036] As shown in the diagram of FIG. **1**, water is introduced at the connector **108** from a first Livshits-Teichner generator **109** for producing water from exhaust gases of the diesel engine **101**. The engine **101** produces exhaust gases with water at a gas pipe **102** as byproduct of the burning reaction in the engine. In the diesel cycle, water vapor is often produced as a byproduct along with unburned hydrocarbons. As shown, part of the exhaust is diverted to the Livshits-Teichner generator **109** for extraction of water as explained hereafter and regeneration of the unburned fuel.

[0037] FIG. **1** shows that the first Livshits-Teichner generator **109** produces water and also traps small sooty particles of carbon that may be transported back into the fuel mixture to improve the efficiency of the overall cycle. FIG. **1** also shows a second Livshits-Teichner generator **105** for extracting water from the exhaust fumes at gas pipe **102**. According to another embodiment described hereinafter, the second Livshits-Teichner generator **105** is used only for capturing water without soot particles to extract potable water at the output **106** of the device. In FIG. **1**, the compressor **103** produces compressed air for operating the first Livshits-Teichner generator **109**, the second Livshits-Teichner generator **105**, and the device for mixing and activations of a fuel mix **110**. One of ordinary skill in the art will recognize that while a compressor **103** is shown as a source for pressurized gas for these devices **109**, **105**, and **110**, what is contemplated is the use of any source of pressurized gas, either from an external source or an internal source, such as the outlet of the Livshits-Teichner generators **105**, **109**.

[0038] FIG. **13** shows the same diagram as found in FIG. **1** but where a second external source of fuel in a tank **1801** is connected to another inlet of the device for mixing and activations of a fuel mix **110**. The source of fuel is a liquefied natural gas or other gaseous fuel released in a third Livshits-Teichner generator **1802** also connected to the compressor **103** for the purpose of vortex mixing, temperature control, or extraction of a fraction of partial pressure of a liquid in suspension in the gas fuel. FIGS. **1** and **13** show generally the versatility of the Livshits-Teichner generator generally as part of any thermodynamic system for the control of the characteristics of a gas, such as the extraction of a liquid from a gas, drying a gas, heating or cooling a gas, or even the possibility of mixing gases.

[0039] Turning now to the Livshits-Teichner generator **105** or **109** itself, which is shown in greater detail in FIG. **2**, the device includes the output of a fluid such as portable water **106** or hydrocarbon-filled condensed water **108** as shown in FIG. **1**. The device has an outer shell made of an external cylindrical housing **204** connected to two end flanges **212**, **206**. Within the main portion of the generator **105**, **109**, a series of Livshits rings **213** are stacked vertically on top of each other. Several embodiments of these rings **213** are shown at FIGS. **3-5**, **10-11**, and **15**. In FIG. **2**, only the top ring **201** and the bottom ring **202** are shown in detail. The other rings are shown figuratively as being stacked between rings **201**, **202**. For example, the Livshits-Teichner generator shown in FIG. **14** shows only two stacked rings **1918**. FIG. **2** illustrates a generator **105** having 10 stacked rings **213**. The use of any number of ring to create a generator of a desired size and configuration is contemplated. The size of the Livshits rings **213** are also calibrated to optimize the flow and create the needed pressure decrease to obtain the proper level of condensation resulting from localized saturation.

[0040] In one embodiment, the Livshits rings **213** are carved out from a single block of metal having high thermal storage capacity. The rings **213** may be made of stainless steel, but other metals, such as, for example, titanium, iron, aluminum, and copper, are contemplated. FIG. **2** shows the Livshits-Teichner generator **105** in a vertical configuration. In this configuration, liquid condensate drops under gravity to the bottom receptacle **205** where it can be collected before exiting the generator **105** via the outlet **106**. While the generator **105** is shown in a vertical orientation, one of ordinary skill in the art of heat exchangers will understand that the orientation of the generator **105** can be changed with adequate design modifications to produce a collection vessel at the bottom of the housing made of a top flange **212**, a bottom flange **206**, and a housing wall **204** fixed using a fixation means to the top and bottom flanges **212**, **206**, respectively.

[0041] In FIG. **2**, the stacked rings **213** are oriented so the largest thickness of metal on the outer edge of the ring is located closest to the middle portion of the generator **105**. While this configuration is optimized to increase thermal inertial and condensation capacity, the rings **213** can be stacked in any configuration within the generator **105**. A heat exchange pipe **203** can be slid into the inner opening of the rings **213** to insulate the incoming gas within the exchanger device for cooling to a release exit gas as shown by the arrow or when insulated and the gas do not mix via the flange opening **207**. As shown by large arrows on the upper and lower ends of the generator **105** in this embodiment, the pipe **203** isolates the structure and allows it to operate as a heat exchange to remove heat from the pipe **203** and ultimately from the exhaust gas. If instead of a pipe **203** capable of insulating the flows, a heat exchanger as shown in FIG. **7** is used, the incoming compressed air shown by the arrows can be merged and mixed into the upcoming stream of gas to be dried. Returning to FIG. **2**, small openings **209** can be made for the compressed and cooled air to reach the flange opening **207** on one side and for the dripping water droplets to enter the receptacle **205** on the other side.

[0042] An opened area **214**, such as a cylindrical internal cavity, can be made between the rings **213** and the pipe **203** to allow for the vortex be created. FIG. **3** is an isometric view of a Livshits ring **213** in a Livshits vortex generator **105**, **109** according to an embodiment of the present disclosure. FIGS. **4-5** are a half- and a semitransparent views of the ring **213** to illustrate the geometry and flow of the compressed air within the ring **213**. Compressed air is placed in contact with the external surface of the ring **213** as shown by the arrow, and more specifically, is in contact with a ring channel **302**. Pressurized gas then flows in openings **303** down into grooves **306** that open into an internal cavity **307** shown here as a cylindrical cavity with a cylindrical surface.

[0043] In one embodiment, to simplify the manufacture of the Livshits ring **213**, the openings **303** are performed in a top surface **308** to the ring channel **302**, and the grooves **306** are carved in the top surface **308**. In a preferred embodiment, the openings **303** are parallel to the principal axis of the Livshits-Teichner generator **105** and tangential to the ring channel **302**, and the grooves **306** are tangential to the openings **303** and are oriented inwardly from the openings **303** to the internal cavity **307** to create a directional flow of the gas traveling along from the ring channel **302** then up and through an opening **303** and through the groove **306** to finally arrive in the internal cavity **307**. Arrows illustrate the directional flow created in the internal cavity **307**.

[0044] Once the gas has traveled along the ring channel **302**, up the opening **303**, and along the groove **306**, it is then released into the internal cavity **307** using the Bernoulli principle but at a different pressure, thus creating a Joule-Thompson cooling effect. The same gas, is then pushed in a vortex configuration in the internal cavity **307** creating a Ranque-Hilsch vortex tube cooling effect. The grooves **306** as shown have a variable section and a rounded lower surface **305** but can also have a flat section. These grooves **306** are once again designed for simplicity in manufacturing (e.g., the need to carve out a groove instead of drilling a full hole) by having the grooves **306** closed by placing the top surface **308** against an adjacent flat surface such as an adjacent Livshits ring **213**. Boring holes to form the passageway for gas from the internal cavity **307** to the openings **303** or even boring a passageway directly from the internal cavity **307** to the ring channel **302** is also contemplated.

[0045] In the above embodiment, the grooves **308** are shown with a variable section that decreases as the groove **308** gets closer to the internal cavity **307**. This configuration allows the limitation and control of the pressure loss along the groove portion and thus create the greatest pressure drop (P_1-P_2) localized at the opening between the groove **308** and the internal cavity **307**. As a consequence, the temperature loss under the Joule-Thompson cooling effect is greatest at the surface of the internal cavity **307**. Also, because of the creation of a vortex in the internal cavity **307** based on the orientation of the grooves **308**, the Ranque-Hilsch vortex tube cooling effect is also greatest at the surface of the internal cavity **307**.

[0046] FIG. **4** shows a particular geometry of the groove openings **309** in the internal cavity **307** and shows how the walls **304** are inclined as part of the ring channel **302** to help with the flow of gas and the transportation of excess condensation. In a preferred embodiment as shown in FIG. **4**, the Livshits ring **213** is made of a single block of metal. The thickest portion of metal between the grooves **308** and the ring channel **302** serves as a heat sink for the accumulation of a greater portion of the heat from the cooling effect at the groove opening **309**. While one configuration of groove is shown, operating in tandem with the openings **303**, resulting in the creation at of two concurring cooling effect on the internal cavity **307**, the creation of any structure capable of recreating these conditions via a series of directional flow channels in structures is contemplated.

[0047] FIG. **6** and associated FIG. **7** illustrate a Livshits ring **213** where an internal heat exchange structure **602** is equipped with different openings **601**, **603** and radial fins for allowing greater surface area connection between an internal gas from an external source **701** and the compressed gas. In one embodiment, the internal heat exchange structure **602** does not cover the area where openings release gas past the groove openings **309** to preserve the Ranque-Hilsch vortex tube cooling effect. While small segments are shown FIGS. **6-7** in the shape of pie slices, FIG. **8** shows a different configuration of heat exchange structure **902** that may be used instead of the internal heat exchange structure **602** where fins are located both on the external **901** and the internal **903** portion of the heat exchange. One obvious advantage is to preserve in the central part of the internal cavity **307** even when equipped with the structure **902** a strong central flow of gas and a capacity to produce a strong vortex.

[0048] FIG. **9** shows yet another type of internal heat exchange structure **1001** made with square external radial fins **1006** with circular openings **1007** and small longitudinal fins **1002**, also with longitudinal square openings. While three different types of internal heat exchange structure **602**, **902**, and **1001** are shown in FIGS. **6-9**, respectively, the use of any type of heat exchange technology, either fixed to the internal cavity **307** of the Livshits ring **213** or a longer structure that can be slid into the internal cavity **307** formed by a plurality of stacked Livshits rings **213** as part of a Livshits-Teichner generator **105**, is contemplated.

[0049] FIG. **12** shows a Livshits-Teichner generator **105** where, in lieu of a rigid heat exchange, a wire mesh **1701** made of a deformed wire is inserted into the internal cavity **307**. In another embodiment of the Livshits ring **213** as shown on FIGS. **10-11**, the internal cavity **307** is smaller in order to maintain a high velocity of air to compensate for the pressure reduction associated with the wire mesh **1701** slid into the internal cavity **307**. By using an internal cavity **307** having a small radius, the Ranque-Hilsch vortex tube cooling effect is increased and the Joule-Thompson cooling effect is proportionally decreased.

[0050] The Livshits-Teichner generator **105** offers many commercial advantages including its compactness, its operation without moving parts, the lack of need for an external energy source aside from a source of pressurized gas, the ability to install this technology on existing systems, and the modular capacity of the system that allows for the change to different configurations by simply changing a portion of the generator. In the case of efficient removal of water and unburned hydrocarbons from exhaust gases, the gases are filtered and reused as part of the cycle for an ultimate reduction in harmful gas emission. While a handful of uses are described, the implementation of this technology to any field where gases or liquids must be mixed, separated, and/or cooled is contemplated.

[0051] FIG. **14** shows another embodiment of the Livshits-Teichner generator **1900** with other flow changes. The generator **1900** still includes an inlet **1909** for the entry of compressed air that ultimately travels along a channel **1907** down a flange opening **1906** to an intermediate flange **1913** and into an internal chamber **1905**, also known as the high-pressure chamber, located between an external housing **1902** and an internal support membrane **1903**. The air then flows into the heart of the generator **1900** from the internal chamber **1905** via a series of windows **1904** made in the internal support membrane **1903**. In one embodiment, these windows **1904** are semi-elliptical in shape, but any geometry of window is contemplated as long as its opening aligns with the ring channels **1917** in each of the Livshits rings **1918**.

[0052] A series of baffles **1912**, **1915**, **1911**, and **1916**, each with different size holes located at different radii from the center, creates a baffle area where the air must travel as shown by the arrow before it leaves the generator **1900**. Bolts are used to connect the top flange **1908** with the bottom flange **1914**, closing the intermediate flange **1913** over both the internal support membrane **1903** and the external housing **1902**. Screws are used along with connection rods **1901** to fasten the device in place. While one industrial method of closure is illustrated, all other commonly known methods are contemplated, such as but not limited to external clips, the use of an external casing, magnetic elements, seal-locked flanges, clipped-in flanges, and the like.

[0053] In the Livshits-Teichner generator **1900**, the bottom Livshits ring as shown is modified to include holes **1919** for draining excess water **1920** that may condense on the external surface of the rings **1918**. FIG. **15** shows another embodiment of a Livshits ring **2000** where drain grooves **2002** and **2005** are made on both the internal **2002** and the external surface **2005** of the ring **2000**. These drain grooves **2002**, **2005** allow for easy transfer of liquid along these surfaces and increase the effective contact area of these surfaces. As shown, the absence of a groove is found in the area where gas is released from the grooves **2004**. While regularly spaced grooves **2002**, **2005** are shown around the periphery of the ring **2000**, the use of any type of passageway capable of transporting fluid or gas effectively from one location to another is contemplated. For example, these grooves **2002**, **2005** may be calibrated in size and shape based on the pressure in the internal chamber **1905** and the surface tension of the liquid to be transported. For example, if water droplets must be able to slide down the grooves, the grooves **2002**, **2005** must be of sufficient size and geometry to allow for droplets to fall down and be transported under their own weight.

[0054] FIG. **16** shows how air can flow in the generator **1900** in the internal chamber **1905** through the different windows (shown by the arrows). FIG. **17** shows the use of a diaphragm **2301** on the internal surface **2303** of the internal cavity. Small holes can be made to offer further reduction in area and create a wider area where the Joule-Thompson cooling effect can take place. An internal biasing element **2304** with small, window-sized areas are aligned with any puncture holes made in the diaphragm **2301** can be used to control the opening of the diaphragm **2301**. The membranes located in the internal surface **2303** area allow for the protection and insulation of the Livshits ring **2000** to prevent heat transfer into the ring **2000**. For example, in a case where primarily the gas must be cooled, such a system may be useful. Finally, FIG. **18** shows a turbine **2501** with pales **2503** that can be inserted into the cavity to recycle a portion of the vortex momentum into electricity.

[0055] In one embodiment, the Livshits-Teichner generator has a cylindrical surface of 245 mm and a height of 800 mm where 15 Livshits rings are stacked in the generator. The use of the Livshits-Teichner generator in conjunction with entry filters to purify the resulting condensate is also contemplated. In yet another embodiment, oil vapor can be removed from compressed air, including, for example, cryogenic devices where pump defects result in evaporation of oil into a very low-pressure stream. Pre- or post-water treatment is also contemplated, such as the inclusion of calcium or other minerals to stabilize demineralized water products. Zeolites can also be used as an alternative to filtration.

[0056] In one embodiment, the apparatus for the condensation of a liquid in suspension in a gas includes a high pressure gas chamber **214** with a pressurized input gas released therein as shown by the arrow in FIG. **16** and where the apparatus includes an opening **303** as shown on FIG. **3** for an expansive release of the pressurized input gas from the high-pressure gas chamber **304** to a low-pressure gas chamber **307** in the embodiment shown in FIG. **3**. The low-pressure gas chamber **307** may include a condensation surface for collecting a portion of the liquid suspended in the gas as the expansive release cools the gas during the passage from a high-pressure state to a low-pressure state and saturates a portion of the liquid suspended in the cooled gas on the condensation surface and the cooling results from a Joule-Thompson expansive cooling of the gas and a Ranque-Hilsch vortex tube cooling of the gas as described above.

[0057] In the apparatus shown in FIG. **3**, the high-pressure gas chamber **304** includes a circumferential cavity on the external portion of a ring **213** and the low-pressure gas chamber **307** is made of a cylindrical internal cavity in the center portion of the ring **213**. The opening **303** may also include a vertical opening shown in dashed lines in FIG. **5** tangential to the circumferential cavity **304** and an angled groove **306** and where the gas is released from the circumferential cavity **304** to the cylindrical internal cavity **307** via the vertical opening **303** and the angled groove **306** and is subsequently released at an angle in the cylindrical internal cavity. The groove **306** may be angled **305** to decrease linearly the section of the groove **306** to increase the speed of the flow.

[0058] FIG. **14** shows a generator **1900** with a baffle area as shown on top **1911**, **1912**, **1915**, and **1916** for the condensation of condensate in the gas moving back up the structure as shown by the arrow. The baffle area may includes a series of adjacent plates **1911**, **1912**, **1915**, and **1916** with a plurality of venting holes **1910** wherein the location of the venting holes on each adjacent place is sufficient to create a serpentine circulation of the gas between adjacent plates. The baffle area may also include a series of adjacent plates with each front and back in opposition, where each plate is in perpendicular alignment with the cylindrical cavity where cooling occurs.

[0059] The rings **213** may include an external surface continuous with the circumferential cavity **304** and an internal surface continuous with the cylindrical internal cavity **307** where both the external surface and the internal surface includes drain grooves a shown in FIG. **18**.

[0060] In another embodiment, the condensation cavity for the condensation of a liquid suspended in a gas includes a low-pressure cylindrical cavity wall shown as the wall of cavity **307** having a length along its axis including a plurality of angled openings created by the grooves **306** shown in FIG. **18** along the length of the cavity for releasing circumferentially within the cylindrical cavity **307** a pressurized gas where the pressurized gas expands at the angled openings into the low-pressure cylindrical cavity **307**, the pressurized gas also enables creation of a vortex of the gas at low pressure into the low-pressure cylindrical cavity **307** for cooling, and the vortex and the expansion cools the high-pressure gas wherein a liquid suspended in the gas condenses on the low-pressure cylindrical cavity wall.

[0061] As shown in FIGS. **2** and **14**, for example, the low-pressure cylindrical cavity wall is formed by stacking at least two rings **213**, each with a cylindrical internal cavity **307** in the center of each ring **213** where the angled openings are a series of grooves **306** made at regular angular intervals shown as 8 grooves along a 360° circle on the radius of each of the at least two rings **213**.

[0062] FIGS. **1** and **13** show a water extraction system for the condensation of a liquid suspended in a gas, the system including a compressor **103** having a pressurized gas outlet for exiting high-pressure gas, a Livshits-Teichner generator **105**, **109**, or **1802**, respectively, with a high-pressure gas chamber **1905** connected to the pressurized gas outlet of the compressor **103** where the high-pressure gas includes a liquid such as water in suspension, and an opening for an expansive release of the pressurized input gas from the high-pressure gas chamber **1905** to a low-pressure gas chamber **307**, wherein the low-pressure gas chamber includes a condensation surface such as the walls of low-pressure gas chamber **307** or the inner grooved surface **3** for collecting a portion of the liquid suspended in the gas.

[0063] The expansive release cools the gas during the passage from a high-pressure state to a low-pressure state and saturates a portion of the liquid suspended in the cooled gas onto the condensation surface, the cooling resulting from a Joule-Thompson expansive cooling of the gas and a Ranque-Hilsch vortex tube cooling of the gas. Water as condensate is then collected in the collector. As shown in FIG. **1**, the high-pressure gas at generator **109** may include exhaust gas **102** from an internal combustion engine **101**.

[0064] Finally, what is described is a method for the collection of a liquid suspended in a gas, comprising the steps of cooling a gas having a liquid in suspension below a saturation temperature of the liquid, wherein the cooling results from a Joule-Thompson expansive release of the gas at an opening and the creation of a Ranque-Hilsch vortex tube cooling within a cavity with the opening, allowing for the cooled gas in the cavity to contact a surface to allow the condensation of a saturated liquid portion at the surface and the collection of the saturated fluid.

[0065] The step of collecting the saturated water with unburned hydrocarbon particles is introduced into an engine producing exhaust gas to improve overall fuel efficiency of the engine, and the water with unburned hydrocarbon particles may be introduced back into the engine using a device for mixing and activation of fuel mix as shown in FIGS. **1** and **13**.

[0066] It is understood that the preceding detailed description of some examples and embodiments of the present invention may allow numerous changes to the disclosed embodiments in accordance with the disclosure made herein without departing from the spirit or scope of the invention. The preceding description, therefore, is not meant to limit the scope of the invention but to provide sufficient disclosure to one of ordinary skill in the art to practice the invention without undue burden.

What is claimed is:

1. An apparatus for the condensation of a liquid suspended in a gas, the apparatus comprising:

a high-pressure gas chamber with a pressurized input gas released therein with a liquid suspended in the input gas; and

an opening for an expansive release of the pressurized input gas from the high-pressure gas chamber to a low-pressure gas chamber, wherein the low-pressure gas chamber includes a condensation surface for collecting a portion of the liquid suspended in the gas,

wherein the expansive release cools the gas during the passage from a high-pressure state to a low-pressure state and saturates a portion of the liquid suspended in the cooled gas onto the condensation surface, and wherein the cooling results from a Joule-Thompson expansive cooling of the gas and a Ranque-Hilsch vortex tube cooling of the gas.

2. The apparatus of claim **1**, wherein the liquid is water and the gas is compressed air.

3. The apparatus of claim **1**, wherein the liquid is water and the gas is a mixture of an engine exhaust gas and compressed air.

4. The apparatus of claim **1**, wherein the high-pressure gas chamber includes a circumferential cavity on the external portion of a ring and the low-pressure gas chamber is a cylindrical internal cavity in the center portion of the ring.

5. The apparatus of claim **4**, wherein the opening comprises a vertical opening tangential to the circumferential cavity and an angled groove, and wherein the gas is released from the circumferential cavity to the cylindrical internal cavity via the vertical opening and the angled groove and is released at an angle in the cylindrical internal cavity.

6. The apparatus of claim **4**, wherein the cylindrical internal cavity includes a tube for the passage of an external gas.

7. The apparatus of claim **4**, wherein the cylindrical internal cavity includes an internal heat exchange structure.

8. The apparatus of claim **7**, wherein the heat exchange structure includes a plurality of radial fins.

9. The apparatus of claim **7**, wherein the heat exchange structure includes internal longitudinal fins and external radial fins.

10. The apparatus of claim **8**, wherein the heat exchange further includes internal and external fins.

11. The apparatus of claim **6**, wherein the tube further includes a filtration element.

12. The apparatus of claim **11**, wherein the filtration element is a wire mesh.

13. The apparatus of claim **1**, further comprising a baffle area for the condensation of condensate.

14. The apparatus of claim **13**, wherein the baffle area includes a series of adjacent plates with a plurality of venting holes, and wherein the location of the venting holes on each adjacent plate is different to create a serpentine circulation of the gas between adjacent plates.

15. The apparatus of claim **4**, further comprising a baffle area with a series of adjacent plates with each front and back in opposition, and wherein each plate is in perpendicular alignment with the cylindrical cavity.

16. The apparatus of claim **4**, wherein the ring includes an external surface continuous with the circumferential cavity and an internal surface continuous with the cylindrical internal cavity, and wherein the external surface includes drain grooves.

17. The apparatus of claim **16**, wherein the internal surface includes drain grooves.

18. The apparatus of claim **4**, wherein the high-pressure gas chamber includes an external housing and an internal support membrane with windows for the passage of the pressurized input gas to the circumferential cavity of the ring.

19. The apparatus of claim **4**, wherein the ring further includes holes between the circumferential cavity and the cylindrical internal cavity for the passage of condensate.

20. The apparatus of claim **4**, further comprising a turbine in the cylindrical internal cavity.

21. The apparatus of claim **4**, further comprising a diaphragm with puncture holes in the cylindrical internal cavity.

22. The apparatus of claim **21**, wherein the diaphragm further includes a biasing element to control the opening of the puncture holes.

23. A condensation cavity for the condensation of a liquid suspended in a gas, the cavity comprising a low-pressure cylindrical cavity wall having a length including a plurality of an angled openings along the length for releasing a pressurized gas circumferentially within the cylindrical cavity, wherein the pressurized gas expands at the angled openings into the low-pressure cylindrical cavity and the pressurized gas also enables for creation of a vortex of the gas at a low pressure into the low-pressure cylindrical cavity for cooling, and wherein the vortex and the expansion cools the high-pressure gas and wherein a liquid suspended in the gas condenses on the low-pressure cylindrical cavity wall.

24. The condensation cavity of claim **23**, wherein the low-pressure cylindrical cavity wall is formed by stacking at least two rings, each with a cylindrical internal cavity in the center of each ring, and wherein the angled openings are a series of grooves made at regular angular intervals on the radius of each of the at least two rings.

25. The apparatus of claim **23**, wherein the liquid is water and the gas is compressed air.

26. The apparatus of claim **23**, wherein the liquid is water and the gas is a mixture of an engine exhaust gas and compressed air.

27. The apparatus of claim **23**, wherein the cylindrical internal cavity includes a tube for the passage of an external gas.

28. The apparatus of claim **23**, wherein the cylindrical internal cavity includes an internal heat exchange structure.

29. The apparatus of claim **27**, wherein the tube further includes a filtration element.

30. The apparatus of claim **24**, wherein at least one ring of the at least two rings includes a cylindrical internal cavity having longitudinal drain grooves.

31. A water-extraction system for the condensation of a liquid suspended in a gas, the system comprising:

a compressor having a pressurized gas outlet for producing high-pressure gas;

a Livshits-Teichner generator with a high-pressure gas chamber connected to the pressurized gas outlet where the high-pressure gas includes a liquid in suspension, and an opening for an expansive release of the pressurized input gas from the high-pressure gas chamber to a low-pressure gas chamber, wherein the low-pressure gas chamber includes a condensation surface for collecting a portion of the liquid suspended in the gas, wherein the expansive release cools the gas during the passage from a high-pressure state to a low-pressure state and saturates a portion of the liquid suspended in the cooled gas onto the condensation surface, and wherein the cooling results from a Joule-Thompson expansive cooling of the gas and a Ranque-Hilsch vortex tube cooling of the gas, and

a water collector for collecting the saturated portion of the liquid in suspension from the Livshits-Teichner generator.

32. The water-extraction system of claim **31**, wherein the high-pressure gas further includes exhaust gas from an engine.

33. The water-extraction system of claim **32**, wherein the engine is a diesel engine.

34. The water-extraction system of claim **32**, wherein the saturated portion of the liquid in suspension includes unburned hydrocarbon particles present in the exhaust gas, and wherein the water collected includes the unburned hydrocarbon particles.

35. The water-extraction system of claim **34**, wherein the system further comprises a fuel mix device connected to a fuel entry of the engine, the compressor, and a fuel tank, and wherein the water collected is mixed into the engine fuel at the fuel mix device.

36. The water-extraction system of claim **35**, wherein the system further comprises a second fuel tank and a second Livshits-Teichner generator connected to the second fuel tank and the fuel mix device.

37. The water-extraction system of claim **31**, wherein the high-pressure gas chamber of the Livshits-Teichner generator includes a circumferential cavity on the external portion of a ring and the low-pressure gas chamber is a cylindrical internal cavity in the center portion of the ring.

38. A method for the collection of a liquid suspended in a gas, comprising:

cooling a gas having a liquid in suspension below a saturation temperature of the liquid in the gas, wherein the cooling results from a Joule-Thompson gas expansive release at an opening and the creation of a Ranque-Hilsch vortex tube cooling in a cavity with the opening;

allowing for the cooled gas in the cavity to contact a surface to allow for the condensation of a saturated liquid at the surface; and

collecting the saturated liquid.

39. The method of claim **38**, wherein the contact surface is selected from the group consisting of a cylindrical internal cavity, a fin, a surface of a wire, or a baffle.

40. The method of claim **38**, wherein the saturated liquid is water and the saturated gas is compressed air.

41. The method of claim **38**, wherein the saturated liquid is water with unburned hydrocarbon particles and the gas is a mixture of an exhaust gas from an engine and compressed air.

42. The method of claim **41**, wherein the step of collecting the saturated water with unburned hydrocarbon particles is introduced into an engine producing the exhaust gas for improving overall fuel efficiency of the engine.

43. The method of claim **42**, wherein the water with unburned hydrocarbon particles is introduced into the engine using a device for mixing and activation of fuel mix.

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