(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
11 March 2021 (11.03.2021)

WIPO | PCT

(10) **International Publication Number**
WO 2021/046476 A1

(51) **International Patent Classification:**
B01D 19/00 (2006.01) ***F04C 19/00*** (2006.01)
F01K 9/02 (2006.01) ***F04F 5/02*** (2006.01)
F02C 3/32 (2006.01) ***F04F 5/10*** (2006.01)

(21) **International Application Number:**
PCT/US2020/049576

(22) **International Filing Date:**
04 September 2020 (04.09.2020)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
62/896,849 06 September 2019 (06.09.2019) US

(71) **Applicant: CARNOT COMPRESSION INC.** [US/US]; 4900 Mill Street, Suite 6, Reno, NV 89502 (US).

(72) **Inventors: SHILLINGER, Danil, Hans**; c/o Carnot Compression Inc., 4900 Mill Street, Suite 6, Reno, NV 89502 (US). **FINLEY, Christopher, David**; c/o Carnot Compression Inc., 4900 Mill Street, Suite 6, Reno, NV 89502 (US). **DUCHATEAU, Christophe**; c/o Carnot Compression Inc., 4900 Mill Street, Suite 6, Reno, NV 89502 (US).

(74) **Agent: CASEY, Timothy, D.**; Baker & Hostetler LLP, Cira Centre, 12th Floor, 2929 Arch Street, Philadelphia, PA 19104-2891 (US).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:
— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) **Title:** A COMPRESSOR WITH EDUCTOR ASSEMBLY

(57) **Abstract:** A gas compressor comprising a substantially hollow cylindrical drum secured to a fixed shaft and configured to rotate a volume of fluid about a central axis. A plurality of eductors may be affixed to the shaft through support rods and positioned within an interior of the drum to receive a flow of fluid during rotation of the drum. A gas inlet along the fixed shaft comprises a channel through which gas external to the drum may be drawn into the eductors and compressed. Compressed gas accumulates within a central area of the drum and may be harvested through a gas outlet along the fixed shaft. Additional embodiments may comprise pitot tubes to manage a fluid level within the drum, and a cooling system to manage fluid temperature.

WO 2021/046476 A1

A COMPRESSOR WITH EDUCTOR ASSEMBLY

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 62/896,849, filed September 6, 2019, the contents of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] Gas compression systems, and more particularly, centrifugal gas compression systems.

BACKGROUND

[0003] In a traditional centrifugal gas compression system, fluid and gas are moved from an inner area to an outer area of a rotating drum through channels of some type, typically tubes. As the liquid and gas move in this manner the gas is compressed and separated from the liquid as it reaches the outer area.

SUMMARY

[0004] A gas compressor comprising a substantially hollow cylindrical drum having a first end and second end opposite the first end, and a substantially hollow shaft secured to the first and second ends of the drum. The drum holds a volume of fluid and may be configured to rotate around the fixed shaft. During rotation, the fluid volume forms an annular lake due to centrifugal forces, and the fluid is at a first level from the interior walls of the drum.

[0005] An eductor assembly comprises a plurality of eductors secured to the fixed shaft through an eductor support rod positioned substantially orthogonally to the fluid flow. The eductors are positioned within the drum within the annular lake and configured to receive a flow of fluid. The fluid velocity creates a suction that draws air into a channel formed along the fixed shaft between an air inlet and the eductors. The gas mixes with the fluid within the eductor and becomes compressed. Upon exiting the eductors, the gas and liquid separate, with the liquid rejoining the annular lake and the gas accumulating in a central portion of the drum. A gas outlet harvests the compressed gas and removes it from the drum.

[0006] A plurality of pitot tubes may be included in the drum to manage the volume of fluid within the drum. Removed fluid may also be cooled and reintroduced to the drum to manage temperature. In various embodiments the fluid may be water and the gas may be air, but other fluids and gases are equally applicable.

[0007] In embodiments, the eductors may be linear or non-linear to optimize fluid flow. The eductors may have a curved and/or streamlined external body to reduce external drag. In some embodiments, a frontal inlet of the eductor is not parallel to a plane defined by an outlet of the eductor.

[0008] In embodiments, the eductors may be located mostly or entirely in the central portion of the drum and (where necessary) fed pressurized liquid via a pitot tube or similar system configured to harvest liquid from the annular lake.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The drawings are provided to illustrate example embodiments described herein and are not intended to limit the scope of the disclosure.

[0010] Figure 1 is an external view of an eductor compressor assembly in accordance with an embodiment;

[0011] Figure 2 is a cross-sectional view of an eductor compressor assembly in accordance with an embodiment.

[0012] Figure 3A is a length-wise cross-sectional view of an eductor compressor assembly during a compression operation in accordance with an embodiment.

[0013] Figure 3B is a cross-sectional view of eductors within an eductor compressor assembly during a compression operation in accordance with an embodiment.

[0014] Figure 3C is a cross-sectional view of pitot tubes within an eductor compressor assembly in accordance with an embodiment.

[0015] Figure 4 is a stator complex for an eductor compressor assembly in accordance with an embodiment.

[0016] Figure 5 is cross-sectional view of a non-linear eductor in accordance with an embodiment.

[0017] Figure 6 is a gas inlet eductor in accordance with an embodiment.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0018] Devices, systems, and methods are described herein for compressing gas through centrifugal action of a compressor drum containing a liquid and a gas. Figure 1 illustrates an exterior view of a compressor assembly, comprising a compressor drum 1, which may be rotatable around a fixed shaft assembly 2. Bearings 6 and seals 11 (shown in Figure 2) may be used to connect the drum and the fixed shaft assembly, while allowing the drum 1 to freely rotate around the shaft 2.

[0019] One or more inlets 3 may be positioned on the fixed shaft 2 and may allow gas and/or fluid to enter the compressor drum 1. One or more outlets 4 and 5 may be positioned along the fixed shaft on an opposite end of the drum and may allow air and/or fluid to exit. In embodiments, liquid can also be introduced through inlet 3, which can double as gas inlet. Inlets 3 may be located on one or both sides of the compressor drum 1. One or more fluid outlets 4 may also be located along the fixed shaft. In embodiments, the fluid outlets may be connected to one or more pitot tubes 10 (shown in Figure 2) located inside the drum, which assist in maintaining a desired fluid level, as further described below. A gas outlet 5 may connect to a central portion of the compressor drum to remove the compressed gas once it reaches a desired pressure.

[0020] Figure 2 illustrates at least a portion of the interior of the compressor drum 1 and the fixed shaft 2. The fixed shaft runs along a central axis of the compressor drum and comprises the stator complex including an eductor assembly of the eductors 7 and eductor support rods 8, as well as gas and fluid inlets 3, a compressed gas outlet 5, and liquid outlet 4. A seal 11, such as a rotary seal, may be provided around the fixed shaft, between a top or bottom wall of the compressor drum, to ensure that undesired and unintentional fluids and gases do not enter or exit the compressor drum. One or more bearings 6 may be included to secure the shaft to the compressor drum and enable smooth rotation of the drum about the shaft and stator complex. In embodiments, the rotating compressor drum 1 may be turned by a drive system (not shown).

[0021] The interior of the fixed shaft may be substantially hollow, and comprise one or more holes, tubing, and pathways to an interior of the compressor drum 1. For example, the compressed gas outlet 5 may run along an interior section of the fixed shaft 2 to provide a pathway to the compressor drum’s interior. One or more compressed gas pathways may comprise holes 9 arranged on an outer portion of the fixed shaft to draw in compressed gas within the drum 1 and transport the gas to an external area for use or storage. Similarly, one or more liquid outlets 4 can comprise tubing running along the interior of the fixed shaft and connect at least one pitot tube 10 within the compressor drum to an external area. The liquid outlets, as further discussed below, can assist in maintaining water levels to desired level and enable implementation of a cooling system.

[0022] Figure 2 further illustrates a plurality of eductors 7 distributed throughout the interior of the drum 1, each secured to a support rod 8 running along a length of the fixed shaft 2. The eductors may be arranged perpendicular to the fixed shaft 2 and configured to remain stationary – like the fixed shaft 2 – to receive a continuous flow of fluid during rotation of the compressor drum. The support rods 8 orthogonally connect to the eductors and provide a hollow pathway between a narrowed section of the eductors (further described below) and the interior of the fixed shaft. As the fluid moves through the rotating compressor drum, see, e.g., (D) in Figure 3B, a pressure differential is created, causing a suction within the gas inlets 3. A supply of gas located external to the drum may be introduced at inlets 3, so that the gas may be drawn along the fixed shaft 2 and support rod 8, into an eductor 7, and mixed with the fluid traveling through the eductor. Upon exiting the eductor, the liquid and gas mixture separates, with the liquid collecting along the drum's interior wall, and the gas accumulating in the central portion. From there, the compressed gas may be drawn into an outlet hole 9, and through a compressed gas outlet 5 along the fixed shaft, to be harvested for one or more applications.

[0023] One or more pitot tubes may be provided within the compressor drum to assist in maintaining or adjusting the fluid level to a desired amount. For example, the pitot tubes may make it possible to remove fluid once the eductors are fully submerged. Similarly, the pitot tubes can indicate when a fluid level is too high or too low and provide information regarding the pressure within the compressor drum.

[0024] It will be appreciated that the number, position, and orientation of the eductors and pitot tubes can vary depending on one or more considerations, including but not limited to a size, shape, or number of eductors, the water flow path during rotation of the compressor drum, potential interference between neighboring eductors, and other cooling, cost, efficiency, and manufacturing considerations.

[0025] Figures 3A, 3B and 3C illustrate the operation of the compressor. Fluid may be introduced through one or more inlets 3. When the compressor has been partially filled with fluid, the compressor drum 1 may be rotated in the direction of rotation (A) by a drive assembly (not shown to simplify the Figure). The rotation of the compressor drum 1 forces the fluid against an interior wall of the drum due to centrifugal forces (B) and forms an annular lake against the interior wall. The fluid level during rotation may be represented by (C), with the annular lake filling the area between the dotted fluid line and the interior wall of the compressor drum.

[0026] In embodiments, the level of fluid (C) within the drum may be adjusted such that the eductors are fully submerged during rotation of the drum 1. The fluid level (C) can, as an example, be increased during operation by injecting and/or spraying fluid into one or more air inlets 3 and decreased by removing liquid through the pitot tubes 10. The fluid level may be automatically adjusted through a control system and one or more sensors (both not shown) measuring characteristics of the gas compression operation.

[0027] Figure 3B depicts how the rotation of the drum (A) creates a flow of fluid through the stationary eductors. In embodiments, the rotation may force the fluid at level (C), which may be enough to fully submerge each of the eductors 7, through the eductors. In embodiments, the eductors may not be fully submerged, but rather only have inlets dipped into the annular lake. In embodiments, the eductors may be fully removed from the annular lake and be fed by tubes, such as pitot tubes, that harvest pressurized liquid from the annular lake. The fluid flow may create a continuous fluid stream (D) through the stationary eductors. The eductors may be designed to take advantage of the Venturi Effect, wherein the flow of liquid through the eductor creates a pressure differential along the length of the eductor. Specifically, the fluid flow at a tapered, narrow region of the eductors has a lower pressure than the wider portions of the flow path, e.g., the eductor inlet and outlet. The lower pressure region creates a suction within the orthogonally connected eductor support rods 8 and draws gas into the eductors through the channel formed between the gas inlets 3, fixed shaft 2, and support rods 8. The gas may be compressed to a first pressure within the eductors, due to mixing with the fluid, and exits the eductors into the interior of the compressor drum 1.

[0028] Upon exiting the eductors, the gas and liquid become separated, due to centrifugal forces and differing densities between the gas and liquid. The denser liquid gets forced towards the interior wall of the rotating drum, where it may rejoin the annular lake, while the gas accumulates in the central portion of the chamber, represented by area (E). As the amount of gas increases in the central portion (E), the pressure within the drum increases and further compresses the gas. Gas can continue being introduced until a desired pressure is reached, at which point the compressed gas may be harvested through the compressed air outlet 5.

[0029] During the compression operation, the gases experience a nearly isothermal compression, as the liquid absorbs the corresponding heat of compression from the gas. This results in an increased temperature of the liquid. As liquid flows through and around the eductors, the friction produces additional heat, which is also absorbed by the fluid and further increases its temperature. To limit the operating temperature of the compression system, a portion of the heated liquid in the annular lake may be drawn out of the compressor drum 1 through one or more pitot tubes 10, and colder liquid can be introduced, e.g., injected or sprayed into the air inlets 3. In embodiments, the heated liquid may be directed to a cooling loop and re-introduced into the compressor drum.

[0030] Figure 3C depicts a cross-sectional, bottom view of the compressor drum 1, and illustrates a flow of fluid through a pair of pitot tubes 10 extending from the fixed shaft 2 into the annular lake area. The pitot tubes may be arranged so as to receive and remove fluid to adjust the level of fluid within the compressor drum. In an example, the pitot tubes can be configured to remove fluid from the annular lake when a certain pressure or fluid level (C) is reached. In another example, measurements from the pitot tubes may indicate when fluid should be added to the compressor drum.

[0031] Figure 4 illustrates a stator complex in accordance with one or more embodiments discussed herein. The stator complex comprises the stationary objects within the compressor drum 1, including the fixed shaft 2, the various gas and fluid inlets and outlets, the plurality of eductors 7, and the eductor support rods 8. In an example, as illustrated in Figure 4, sets of eductors and/or sets of eductors and pitot tubes may be secured to the fixed shaft. Each set of eductors and pitot tubes may attach to a support ring secured to, or a part of, the fixed shaft 2.In various embodiments, each set may comprise a pair of eductors or pitot tubes, and may be positioned such that each eductor/pitot tube pair has a 90° offset around the fixed shaft from a neighboring set. The stator complex may comprise three eductor pairs and a pair of pitot tubes, however more or less eductors and/or pitot tubes may be provided. Each pair of eductors/pitot tubes may also be positioned around the shaft with a 180° separation, as illustrated in Figure 4. In other examples, each eductor/pitot tube in the set may be separated by equal angles around the shaft and distances between each pair of eductors or pitot tubes may be fixed.

[0032] In addition, any of a number of eductors, pitot tubes, and sets of either eductors or pitot tubes, may extend from the fixed shaft in variety of arrangements to optimize gas recovery and efficiency. Arrangements may also depend, for example, on one or more design characteristics including but not limited to size, cost, and manufacturing considerations.

[0033] Figure 5 illustrates a cross-sectional view of a non-linear exterior shaped eductor. A cylindrical compressor drum results in an annular lake being formed along the interior wall. Accordingly, the fluid flow during rotation is circular, and may be optimally received by a non-linear exterior shaped eductor, such as the curved eductor illustrated in Figure 5, which may still include a linear interior fluid path. Eductors may have a streamlined body 19 such as a curved front end to facilitate fluid flow both through and around the eductor and decrease fluid resistance while traveling through the annular lake. It will be noted, however, that a linear eductor, or other shaped eductor design may be used in accordance with one or more embodiments discussed herein.

[0034] With respect to the eductor of Figure 5, fluid may enter the eductor through a front inlet 12 having a first width. The front inlet 12 may be shaped to match accordingly with the streamlined body 19 at the front end of the eductor, to optimize the fluid flow into the eductor. The fluid flow moves from the front inlet 12 through a nozzle 15 within suction chamber 16. The nozzle 15 has a significantly smaller width than the suction chamber 16, resulting in a pressure drop. In embodiments, the suction chamber may have a same or different width than the front inlet 12. Since the fluid velocity through the entire eductor will remain constant when the compressor drum rotates at a constant speed, the velocity through the narrower nozzle section 15 must be greater than the flow rate through the wider suction chamber 16. Thus, the increase results in a drop in pressure in the nozzle section 15.

[0035] Suction chamber 16 utilizes the pressure drop to introduce gas into the system. An eductor suction inlet 13 may be located within the eductor support rod 8 and attached substantially orthogonal to the suction chamber 16, however the position of the eductor support inlet may vary to optimize an amount of gas drawn in. A decrease in pressure from the nozzle creates a suction within the suction chamber 16 and draws gas through the suction inlet 13 from a source external to the compressor drum. In particular, shear forces within the suction chamber 16 cause a momentum transfer from the flowing fluid to the gas and creates a suction. As discussed above, the suction inlet 13 is part of a channel running through the support rod 8 and fixed shaft 2 to introduce gas into the eductors and the compressor drum 1.

[0036] After entering the suction chamber 16, the uncompressed gas enters a mixing tube 17, where the gas and fluid mix. In embodiments, as noted above, the mixing tube 17 may have a greater width than the nozzle, be substantially linear, and run along a significant length of the eductor. A divergent section 18 may follow the mixing tube 17. In this region, the gas may be partially compressed due to a pressure increase and interactions with the fluid, which may be an incompressible fluid, such as water. From there the fluid and gas mixture exits the eductor and enters the interior of the compressor drum.

[0037] Figure 6 illustrates an additional embodiment wherein an eductor operates as an inlet booster. As discussed above, during compression operations, heated fluid may be removed from the compressor drum, passed through a cooling system, and reintroduced intro the compressor drum. The reintroduction of the cooled fluid may be done in a number of ways, including with an eductor 20 placed at a point of re-entry into the compressor drum, e.g., at the gas inlet 3 as shown in Figure 3A, to increase an amount of gas flow into the compressor drum.

[0038] Figure 6 illustrates an example operation of the inlet booster eductor 20, with water as the fluid, and air as the gas, as an inlet for a centrifugal gas compressor of the type disclosed herein. Water from a cooling system (not shown) drives the fluid through the eductor. As discussed above, with reference to Figure 5, an eductor has a narrowed nozzle section, which creates an orthogonal suction. The suction draws air, e.g., ambient air into the eductor, where it may be mixed with the water in the convergent-divergent section and drawn into the compressor inlet.

[0039] An inlet eductor can greatly increase the gas flow into the compressor drum and increase the volume of gas available for compression operations. A greater compressor inlet pressure, for example, results in a greater gas flow and can reduce the work requirement for compression operations within the drum. It will be appreciated that any of plurality of sized eductors, nozzle sizes, etc., may be incorporated to achieve an ideal gas flow according to one or more desired characteristics of the system. In addition, an eductor inlet booster may be advantageous in various other types of compressor systems, including but not limited to cassette systems, eductor-based systems, and other centrifugal compressors, such as that described in U.S. Patent No. 10,359,055, the contents of which is incorporated herein by reference.

[0040] For example, in an embodiment, a gas compressor may comprise a substantially hollow cylindrical drum having a first end and a second end opposite the first end, and configured to rotate about a central axis, a substantially hollow shaft secured to the first and second ends of the drum, and a gas compression assembly configured to receive gas at a gas inlet from external to the drum, to compress the gas, and to output the compressed gas to a gas harvesting system. The eductor may be positioned at the gas inlet and be configured to increase air flow into the gas inlet and to introduce cooled external fluid into the drum driven through the gas inlet eductor. Rotation of the drum may cause fluid within the drum to form an annular lake having a fluid level and fluid from the annular lake may be fed into the gas compression assembly. The cooled external fluid flow may create a suction drawing the gas into the gas inlet eductor mixing the gas with the cooled external fluid. Upon exiting the gas inlet eductor, the cooled external fluid may separate from the gas and accumulate within the annular lake while the gas may enter the gas compression assembly.

[0041] In an embodiment, a gas compressor may comprise a substantially hollow cylindrical drum having a first end and a second end opposite the first end, and configured to rotate about a central axis; a substantially hollow shaft secured to the first and second ends of the drum; an eductor assembly affixed to the shaft, the eductor assembly comprising a plurality of eductors each secured to the shaft by an eductor support rod; at least one gas inlet along the shaft, the gas inlet creating a channel between an area external to the drum, along the fixed shaft and through each of the eductor support rods to the eductors; and at least one gas outlet creating a channel along an interior of the shaft, between a central, interior portion of the drum and a gas harvesting system; wherein rotation of the drum causes fluid within the drum to form an annular lake having a fluid level, wherein fluid from the annular lake is fed into each of the eductors to create a fluid flow through each of the eductors, wherein the fluid flow creates a suction drawing the gas into each of the eductors through the channel formed by the gas inlet, and the gas is mixed with the fluid, wherein upon exiting the eductors, compressed gas separates from the fluid and accumulates within a central portion of the drum between the annular lake, wherein gas becomes compressed as an amount of gas increases within the central portion, and wherein the compressed gas is harvested through a gas outlet.

[0042] In the embodiment, wherein each of the eductors are fully submerged in the annular lake.

[0043] In the embodiment, wherein the gas is air and the fluid is water.

[0044] In the embodiment, further comprising a cooling system to remove heated fluid from the drum, cool the heated fluid, and reintroduce the cooled fluid into the drum.

[0045] In the embodiment, further comprising an eductor at the gas inlet.

[0046] In the embodiment, wherein the eductor at the gas inlet receives recycled fluid reintroduced into the drum.

[0047] In the embodiment, wherein the eductors further comprise an inlet, a suction section comprising a nozzle, a mixture section, and a divergent section, wherein the eductor support rod is connected substantially orthogonally to the suction section.

[0048] In the embodiment, wherein the eductor has a non-linear shape.

[0049] In the embodiment, wherein at least one of an internal fluid channel and an external body of the eductor is curved to optimize fluid flow.

[0050] In the embodiment, wherein a plane defined by a frontal inlet of the eductor is not parallel to the plane defined by an outlet of the eductor.

[0051] In the embodiment, wherein an external surface of the eductor is streamlined to reduce external drag.

[0052] In the embodiment, further comprising at least one pitot tube configured to remove a volume of fluid to adjust the fluid level within the drum.

[0053] In the embodiment, further comprising a pressurized gas harvesting system at the gas outlet.

[0054] In the embodiment, wherein each of the eductors has a fluid inlet that is at least partially submerged in the annular lake.

[0055] In the embodiment, wherein each of the eductors has a fluid inlet, and further comprising at least one tube configured to be at least partially submerged in the annular lake and to feed fluid to the fluid inlet.

[0056] In an embodiment, a gas compression method may comprise rotating a substantially hollow cylindrical drum about a central axis, wherein the drum contains a volume of fluid, has a first end and a second end opposite the first end, each secured to a substantially hollow shaft, and wherein an eductor assembly comprising a plurality of eductors is secured to the support shaft by an eductor support rod is affixed to the shaft;

forming an annular lake having a fluid level within the drum and creating a fluid flow through each of the eductors, wherein the fluid flow creates a suction drawing gas external to the drum into each of the eductors through a gas inlet channel formed along the fixed shaft through each of the eductor support rods to the eductors; upon exiting the eductor, collecting compressed gas at a central portion of the drum between the annular lake; and harvesting the compressed gas through a gas outlet.

[0057] In the embodiment, wherein each of the eductors are fully submerged in the annular lake.

[0058] In the embodiment, wherein the gas is air and the fluid is water.

[0059] In the embodiment, further comprising removing and cooling fluid from the drum, and reintroducing the cooled fluid into the drum.

[0060] In the embodiment, further comprising providing an eductor at the gas inlet to increase air flow into the gas inlet channel, the cooled fluid driven through the gas inlet eductor and into the drum.

[0061] In the embodiment, further comprising managing a fluid level using one or more pitot tubes within the drum.

[0062] In the embodiment, further comprising improving fluid flow suction through an eductor by providing at least one of a curved fluid channel within the eductor, a eductor inlet and outlet on unparallel planes, and a streamlined eductor body.

[0063] In the embodiment, wherein each of the eductors has a fluid inlet that is at least partially submerged in the annular lake.

[0064] In the embodiment, wherein each of the eductors has a fluid inlet, and further comprising at least one tube configured to be at least partially submerged in the annular lake and to feed fluid to the fluid inlet.

[0065] It will be understood that various aspects or details of the invention(s) may be changed without departing from the scope of the disclosure and invention. It is not exhaustive and does not limit the claimed inventions to the precise form disclosed. Furthermore, the foregoing description is for the purpose of illustration only, and not for the purpose of limitation. Modifications and variations are possible in light of the above description or may be acquired from practicing the invention. The claims and their equivalents define the scope of the invention(s).

What is claimed:

1. A gas compressor, comprising:

a substantially hollow cylindrical drum having a first end and a second end opposite the first end, and configured to rotate about a central axis;

a substantially hollow shaft secured to the first and second ends of the drum;

an eductor assembly affixed to the shaft, the eductor assembly comprising a plurality of eductors each secured to the shaft by an eductor support rod;

at least one gas inlet along the shaft, the gas inlet creating a channel between an area external to the drum, along the fixed shaft and through each of the eductor support rods to the eductors; and

at least one gas outlet creating a channel along an interior of the shaft, between a central, interior portion of the drum and a gas harvesting system;

wherein rotation of the drum causes fluid within the drum to form an annular lake having a fluid level, wherein fluid from the annular lake is fed into each of the eductors to create a fluid flow through each of the eductors, wherein the fluid flow creates a suction drawing the gas into each of the eductors through the channel formed by the gas inlet, and the gas is mixed with the fluid, wherein upon exiting the eductors, compressed gas separates from the fluid and accumulates within a central portion of the drum between the annular lake, wherein gas becomes compressed as an amount of gas increases within the central portion, and wherein the compressed gas is harvested through a gas outlet.

2. The gas compressor of claim 1, wherein each of the eductors are fully submerged in the annular lake.

3. The gas compressor of claim 1, wherein the gas is air and the fluid is water.

4. The gas compressor of claim 1, further comprising a cooling system to remove heated fluid from the drum, cool the heated fluid, and reintroduce the cooled fluid into the drum.

5. The gas compressor of claim 1, further comprising an eductor at the gas inlet.

6. The gas compressor of claim 5, wherein the eductor at the gas inlet receives recycled fluid reintroduced into the drum.

7. The gas compressor of claim 1, wherein the eductors further comprise:

an inlet, a suction section comprising a nozzle, a mixture section, and a divergent section, wherein the eductor support rod is connected substantially orthogonally to the suction section.

8. The gas compressor of claim 1, wherein the eductor has a non-linear shape.

9. The gas compressor of claim 8, wherein at least one of an internal fluid channel and an external body of the eductor is curved to optimize fluid flow.

10. The gas compressor of claim 1, wherein a plane defined by a frontal inlet of the eductor is not parallel to the plane defined by an outlet of the eductor.

11. The gas compressor of claim 1, wherein an external surface of the eductor is streamlined to reduce external drag.

12. The gas compressor of claim 1, further comprising at least one pitot tube configured to remove a volume of fluid to adjust the fluid level within the drum.

13. The gas compressor of claim 1, further comprising a pressurized gas harvesting system at the gas outlet.

14. The gas compressor of claim 1, wherein each of the eductors has a fluid inlet that is at least partially submerged in the annular lake.

15. The gas compressor of claim 1, wherein each of the eductors has a fluid inlet, and further comprising at least one tube configured to be at least partially submerged in the annular lake and to feed fluid to the fluid inlet.

16. A gas compression method, comprising:

rotating a substantially hollow cylindrical drum about a central axis, wherein the drum contains a volume of fluid, has a first end and a second end opposite the first end, each secured to a substantially hollow shaft, and wherein an eductor assembly comprising a plurality of eductors is secured to the support shaft by an eductor support rod is affixed to the shaft;

forming an annular lake having a fluid level within the drum and creating a fluid flow through each of the eductors,

wherein the fluid flow creates a suction drawing gas external to the drum into each of the eductors through a gas inlet channel formed along the fixed shaft through each of the eductor support rods to the eductors;

upon exiting the eductor, collecting compressed gas at a central portion of the drum between the annular lake; and

harvesting the compressed gas through a gas outlet.

17. The gas compression method of claim 16, wherein each of the eductors are fully submerged in the annular lake.

18. The gas compression method of claim 16, wherein the gas is air and the fluid is water.

19. The gas compression method of claim 16, further comprising removing and cooling fluid from the drum, and reintroducing the cooled fluid into the drum.

20. The gas compression method of claim 19, further comprising providing an eductor at the gas inlet to increase air flow into the gas inlet channel, the cooled fluid driven through the gas inlet eductor and into the drum.

21. The gas compression method of claim 16, further comprising managing a fluid level using one or more pitot tubes within the drum.

22. The gas compression method of claim 16, further comprising improving fluid flow suction through an eductor by providing at least one of a curved fluid channel within the eductor, a eductor inlet and outlet on unparallel planes, and a streamlined eductor body.

23. The gas compressor method of claim 16, wherein each of the eductors has a fluid inlet that is at least partially submerged in the annular lake.

24. The gas compressor method of claim 16, wherein each of the eductors has a fluid inlet, and further comprising at least one tube configured to be at least partially submerged in the annular lake and to feed fluid to the fluid inlet.

25. A gas compressor, comprising:

a substantially hollow cylindrical drum having a first end and a second end opposite the first end, and configured to rotate about a central axis;

a substantially hollow shaft secured to the first and second ends of the drum;

a gas compression assembly configured to receive gas at a gas inlet from external to the drum, to compress the gas, and to output the compressed gas to a gas harvesting system; and

an eductor at the gas inlet configured to increase air flow into the gas inlet and to introduce cooled external fluid into the drum driven through the gas inlet eductor,

wherein rotation of the drum causes fluid within the drum to form an annular lake having a fluid level, wherein the fluid from the annular lake is fed into the gas compression assembly.

26. The gas compressor of claim 25, wherein the cooled external fluid flow creates a suction drawing the gas into the gas inlet eductor mixing the gas with the cooled external fluid, wherein upon exiting the gas inlet eductor the cooled external fluid separates from the gas and accumulates within the annular lake while the gas enters the gas compression assembly.

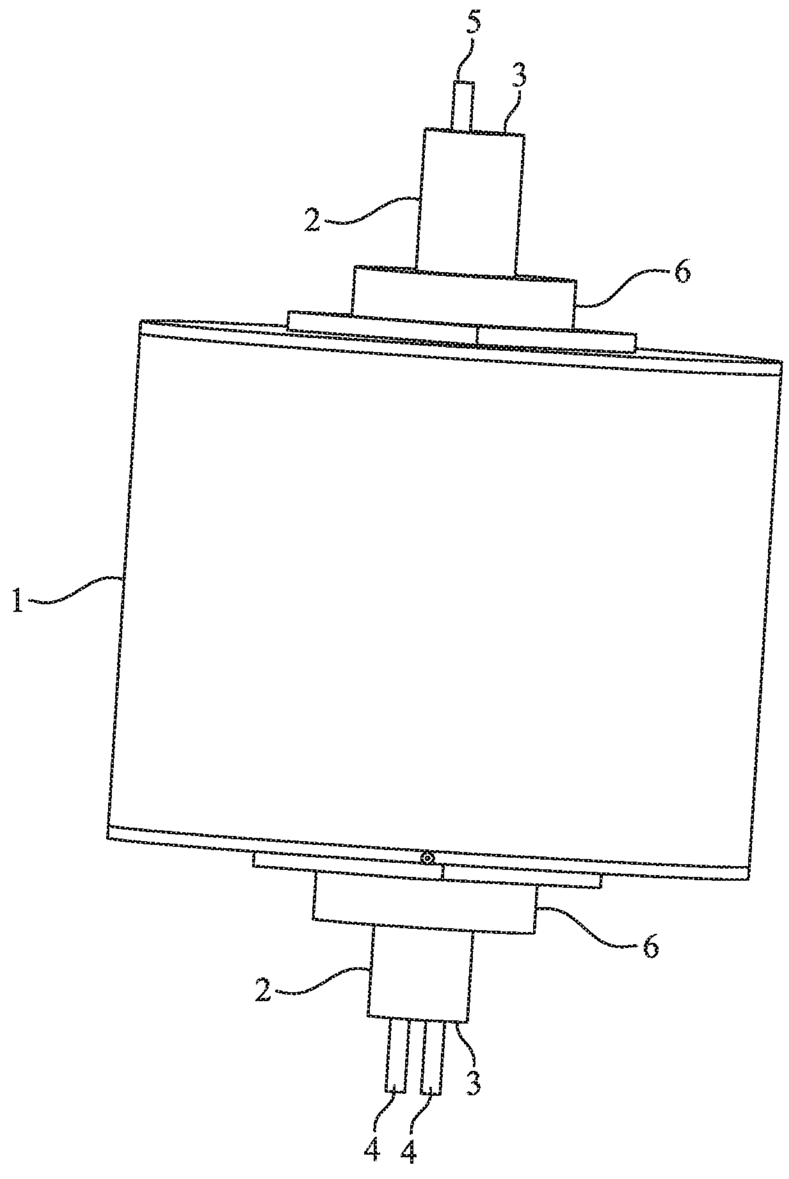

Figure 1

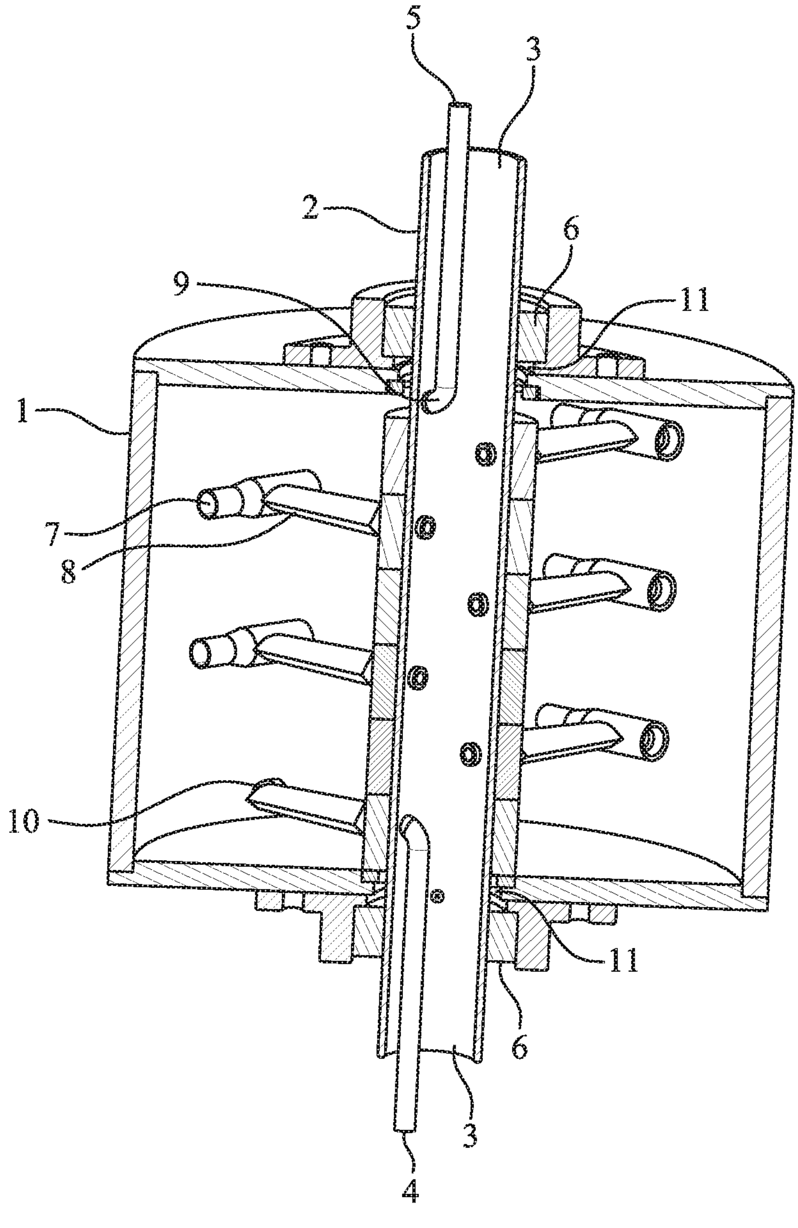

Figure 2

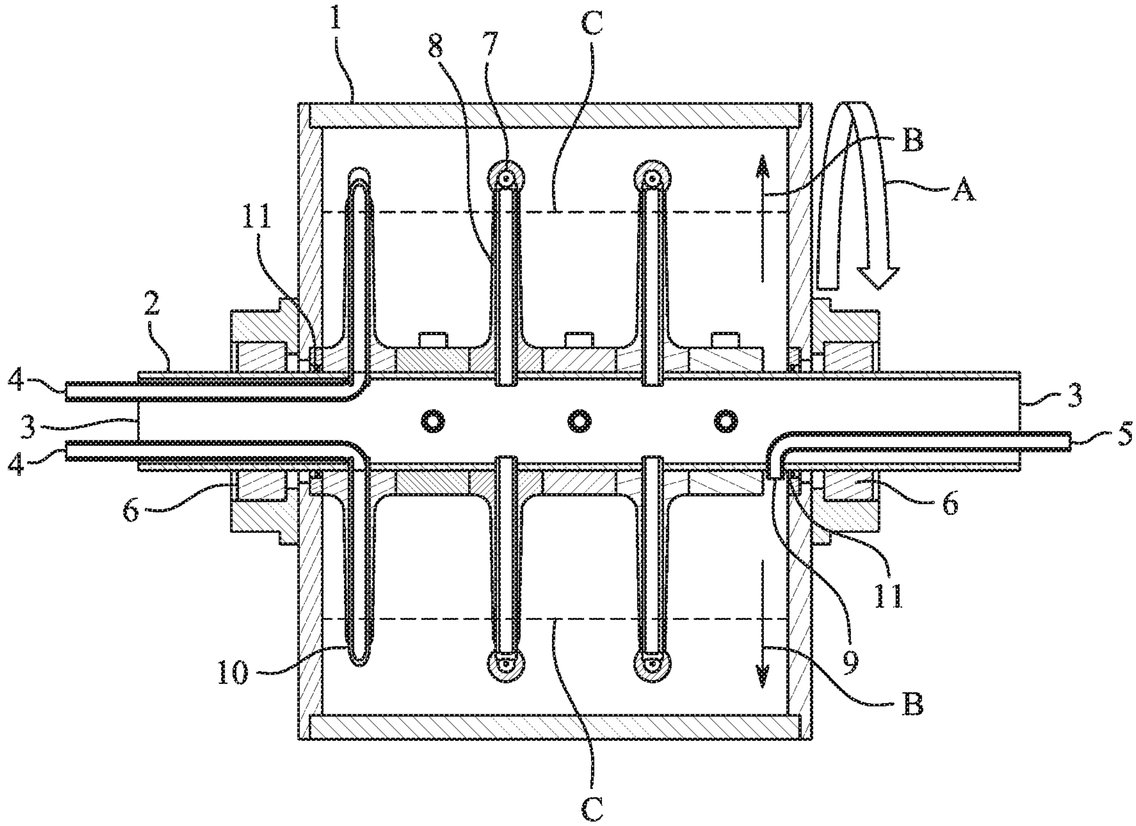

Figure 3A

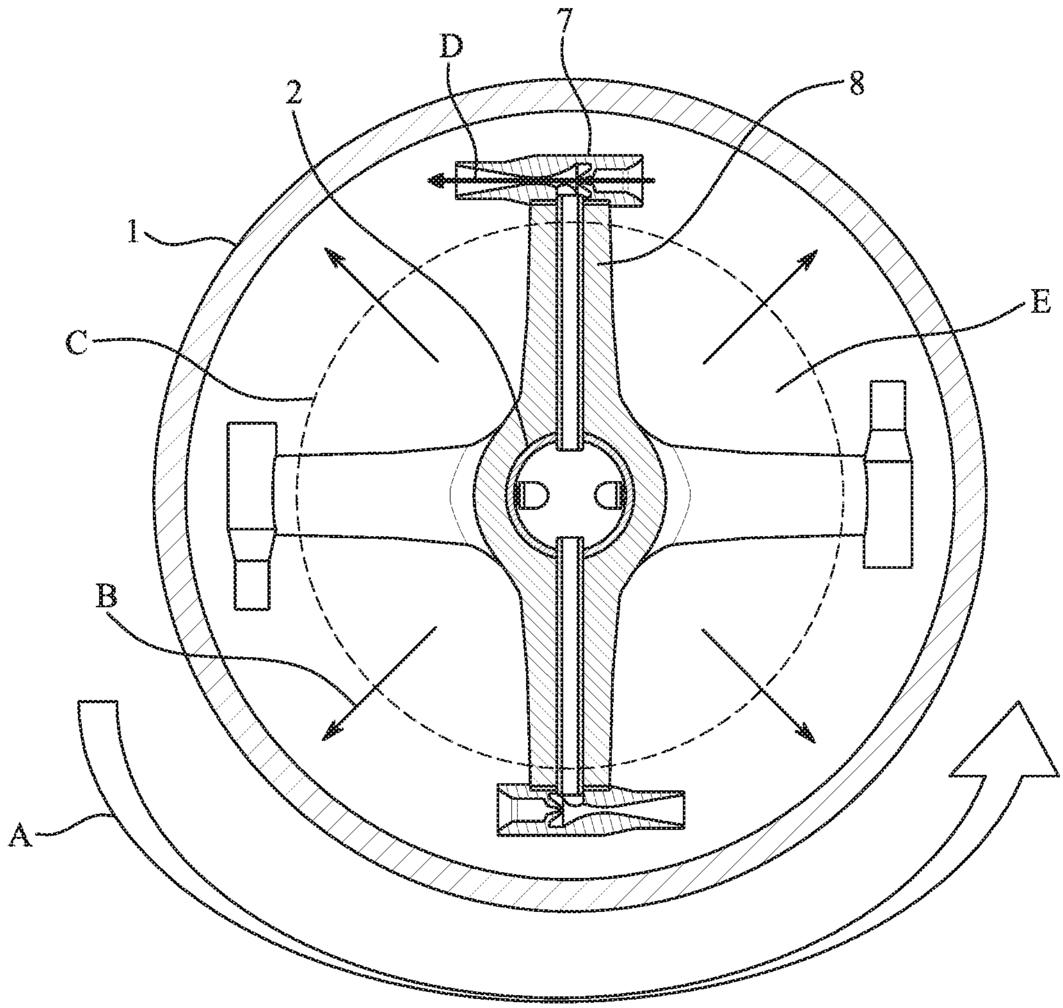

Figure 3B

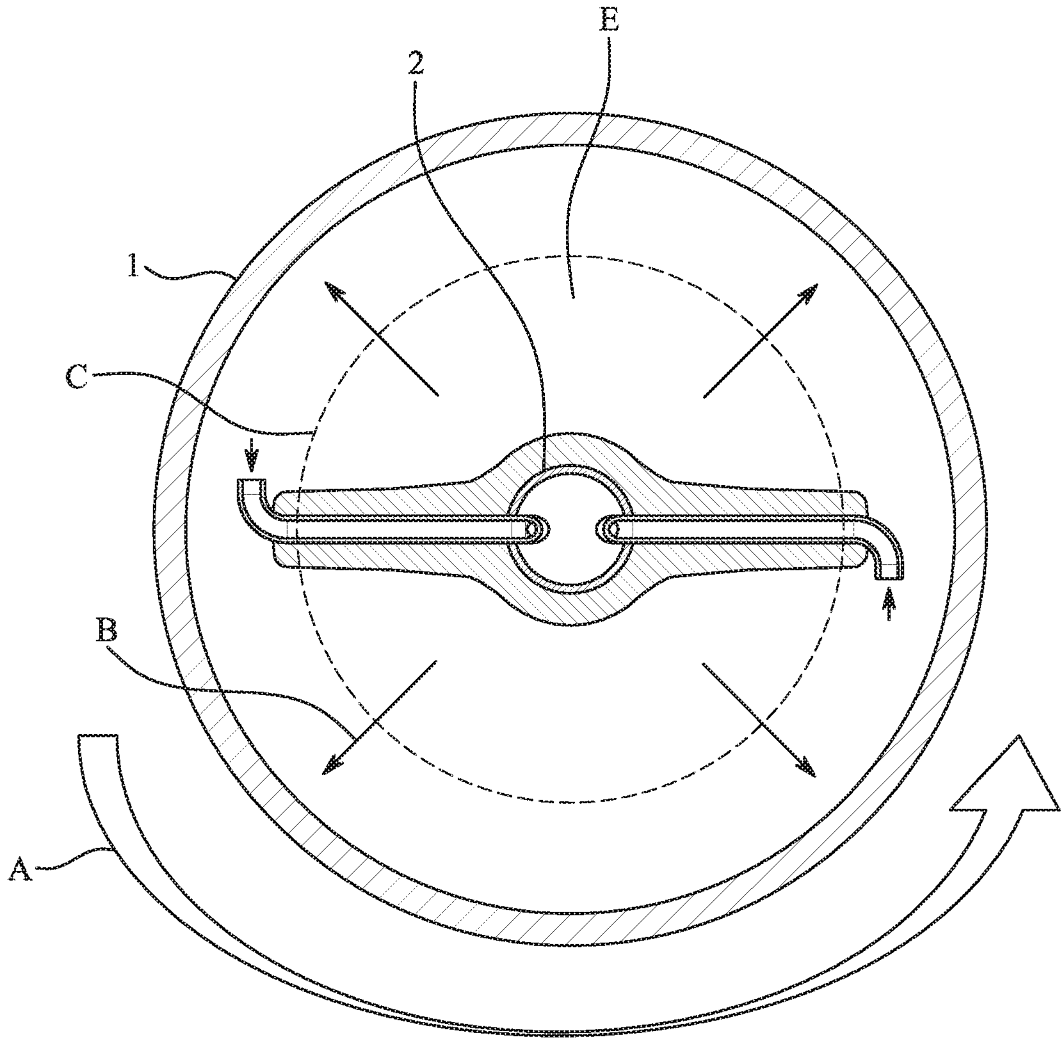

Figure 3C

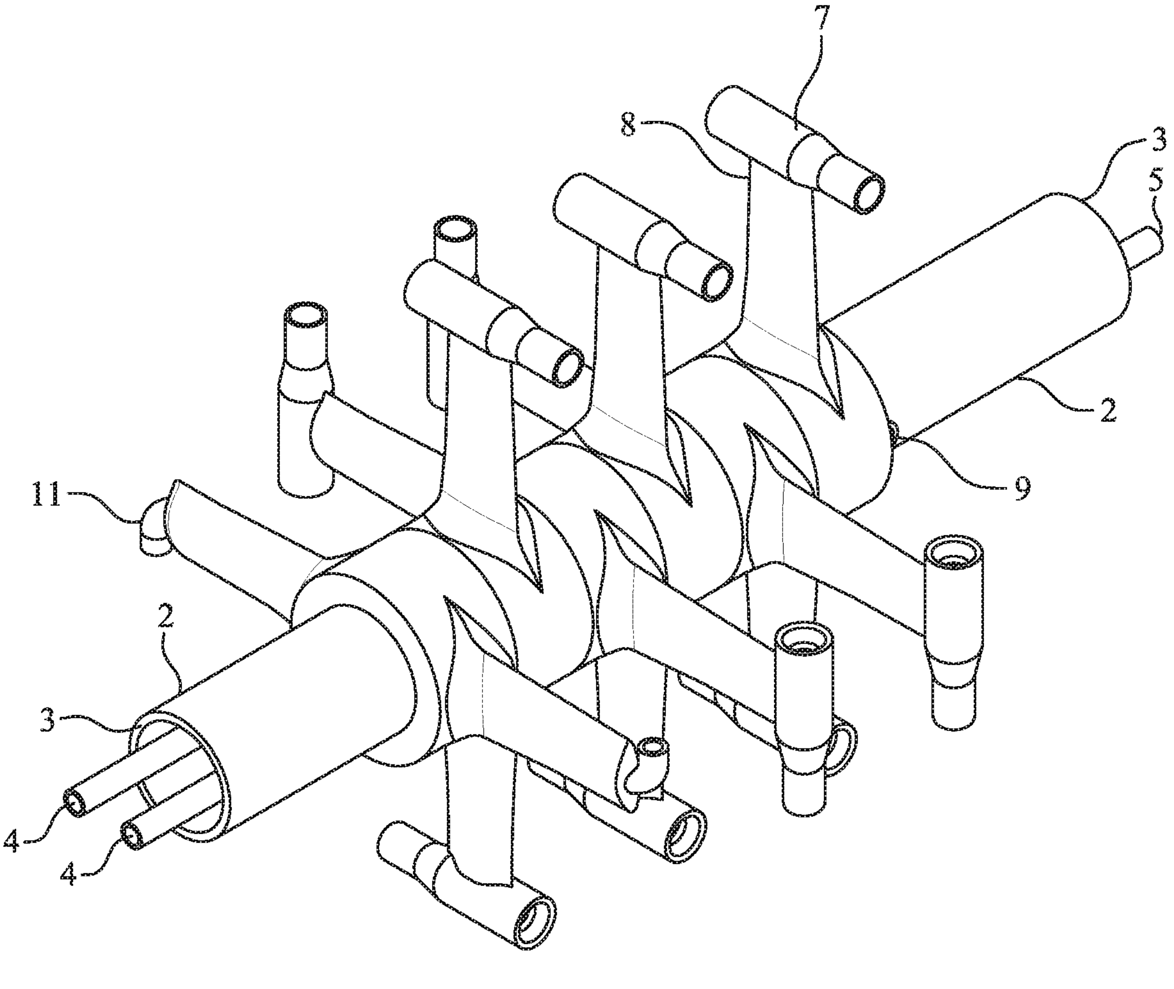

Figure 4

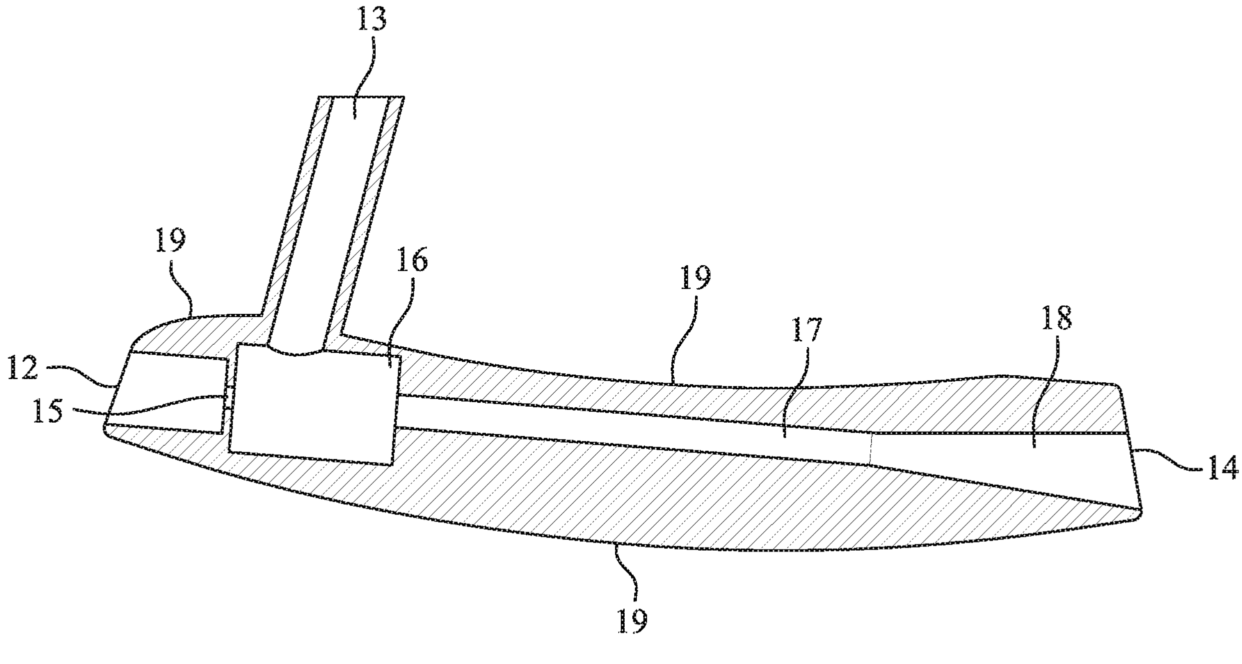

Figure 5

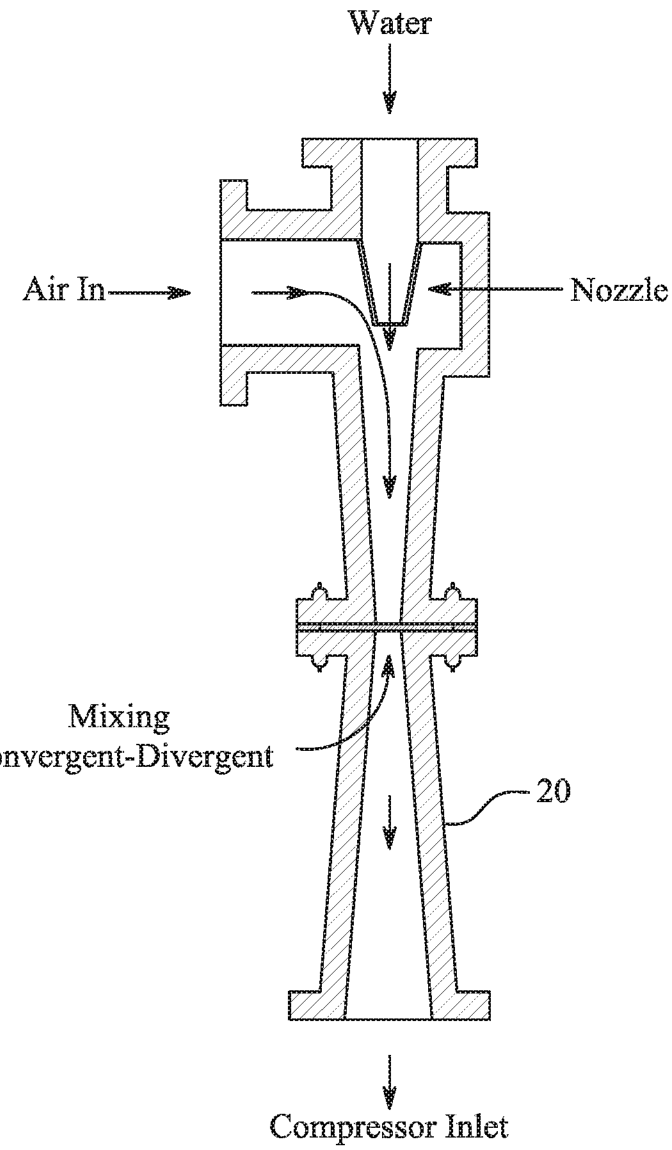
Water
Air In
Nozzle
Mixing
Convergent-Divergent
20
Compressor Inlet

Figure 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 20/49576

A. CLASSIFICATION OF SUBJECT MATTER

IPC - B01D 19/00, F01K 9/02, F02C 3/32, F04C 19/00, F04F 5/02, F04F 5/10 (2020.01)

CPC - B01D 19/0042, B01D 19/0057, F01K 9/02, F01K 23/02, F02C 3/02, F02C 3/16, F02C 3/32, F04C 19/00, F04D 17/167, F04D 17/18, F04D 31/00, F04D 29/706, F04F 5/02, F04F 5/10, F05D 2210/12, F05D 2210/13, F05D 2210/132, F05D 2220/3216, F05D 2220/3218, F05D 2240/128, F05D 2250/31, F05D 2250/411, F05D 2250/231, F05D 2260/43, F17C 2227/0114, B01F 3/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2015/0023807 A1 (ROTATIONAL TROMPE COMPRESSORS, LLC) 22 January 2015 (22.01.2015), Fig. 1; para [0035], [0040], [0056]-[0059], [0064], [0078], [0080], [0089]	1-15, 25-26
A	US 2010/0270223 A1 (ARNAUD) 28 October 2010 (28.10.2010), Figs. 2, 26; para [0039], [0042], [0145]	1-15, 25-26
A	US 6,713,028 B1 (OKLEJAS, JR.) 30 March 2004 (30.03.2004), col 8, ln 10-67	1-15, 25-26
A	US 4,027,993 A (WOLFF) 07 June 1977 (07.06.1977), col 3, ln 52-59; col 12, ln 16-43	1-15, 25-26
A, P	US 2020/0277970 A1 (CARNOT COMPRESSION INC.) 03 September 2020 (03.09.2020), para [0006]-[0048]	1-15, 25-26

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 January 2021	02 FEB 2021

Name and mailing address of the ISA/US	Authorized officer
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Lee Young Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 20/49576

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I: Claims 1-15, 25-26, drawn to gas compressors.

Group II: Claims 16-24, drawn to a gas compression method.

-- Please See Supplemental Box

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-15, 25-26

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Continued from Box No. III, Observations where unity of invention is lacking,

The inventions listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Special Technical Features

Group II does not require a gas compressor, comprising: a substantially hollow cylindrical drum having a first end and a second end opposite the first end, and configured to rotate about a central axis; a substantially hollow shaft secured to the first and second ends of the drum; an eductor assembly affixed to the shaft, the eductor assembly comprising a plurality of eductors each secured to the shaft by an eductor support rod; at least one gas inlet along the shaft, the gas inlet creating a channel between an area external to the drum, along the fixed shaft and through each of the eductor support rods to the eductors; and at least one gas outlet creating a channel along an interior of the shaft, between a central, interior portion of the drum and a gas harvesting system; wherein rotation of the drum causes fluid within the drum to form an annular lake having a fluid level, wherein fluid from the annular lake is fed into each of the eductors to create a fluid flow through each of the eductors, wherein the fluid flow creates a suction drawing the gas into each of the eductors through the channel formed by the gas inlet, and the gas is mixed with the fluid, wherein upon exiting the eductors, compressed gas separates from the fluid and accumulates within a central portion of the drum between the annular lake, wherein gas becomes compressed as an amount of gas increases within the central portion, and wherein the compressed gas is harvested through a gas outlet; and
a gas compressor, comprising: a substantially hollow cylindrical drum having a first end and a second end opposite the first end, and configured to rotate about a central axis; a substantially hollow shaft secured to the first and second ends of the drum; a gas compression assembly configured to receive gas at a gas inlet from external to the drum, to compress the gas, and to output the compressed gas to a gas harvesting system; and an eductor at the gas inlet configured to increase air flow into the gas inlet and to introduce cooled external fluid into the drum driven through the gas inlet eductor, wherein rotation of the drum causes fluid within the drum to form an annular lake having a fluid level, wherein the fluid from the annular lake is fed into the gas compression assembly, as required by Group I.

Group I does not require a gas compression method, comprising: rotating a substantially hollow cylindrical drum about a central axis, wherein the drum contains a volume of fluid, has a first end and a second end opposite the first end, each secured to a substantially hollow shaft, and wherein an eductor assembly comprising a plurality of eductors is secured to the support shaft by an eductor support rod is affixed to the shaft; forming an annular lake having a fluid level within the drum and creating a fluid flow through each of the eductors, wherein the fluid flow creates a suction drawing gas external to the drum into each of the eductors through a gas inlet channel formed along the fixed shaft through each of the eductor support rods to the eductors; upon exiting the eductor, collecting compressed gas at a central portion of the drum between the annular lake, as required by Group II.

Shared Common Features

The only feature shared by Groups I and II that would otherwise unify the groups is a hollow cylindrical drum having a first end and a second end opposite the first end; a substantially hollow shaft secured to the first and second ends of the drum; fluid flow creates a suction drawing gas external to the drum into an eductor; a pluralarity of eductors; compressed gas at a central portion of the drum between an annular lake; and compressed gas is harvested through a gas outlet. However, this shared technical feature does not represent a contribution over prior art, because the shared technical feature is anticipated by US 2015/0023807 A1 to Cherry, et al. (hereinafter 'Cherry'). Cherry discloses a hollow cylindrical drum having a first end and a second end opposite the first end (Fig. 1; para [0035], [0057], [0056], cylinder container with inlet side, 18, outlet side, 21, and chamber, 24.); a substantially hollow shaft secured to the first and second ends of the drum (para [0035], [0058], piston compressor with outlet port, 25, as shown.); fluid flow creates a suction drawing gas external to the drum into an eductor (para [0080], vortex generator with venturi nozzles inject gas-liquid into compressors.); a plurality of eductors (para [0078], [0080], venturi nozzles, 121 121a.); compressed gas at a central portion of the drum between an annular lake (para [0059], [0064], compressed bubbles in chamber, 24, surrounded by liquid, 30.); and compressed gas is harvested through a gas outlet (para [0089], annular compressed gas collection space.).

As the technical features were known in the art at the time of the invention, this cannot be considered a special technical feature that would otherwise unify the groups.

Groups I and II therefore lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.