



(12) **DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION**

(13) **A1**

(22) Date de dépôt/Filing Date: 2021/06/04
(41) Mise à la disp. pub./Open to Public Insp.: 2021/12/22
(30) Priorité/Priority: 2020/06/22 (US16/908,726)

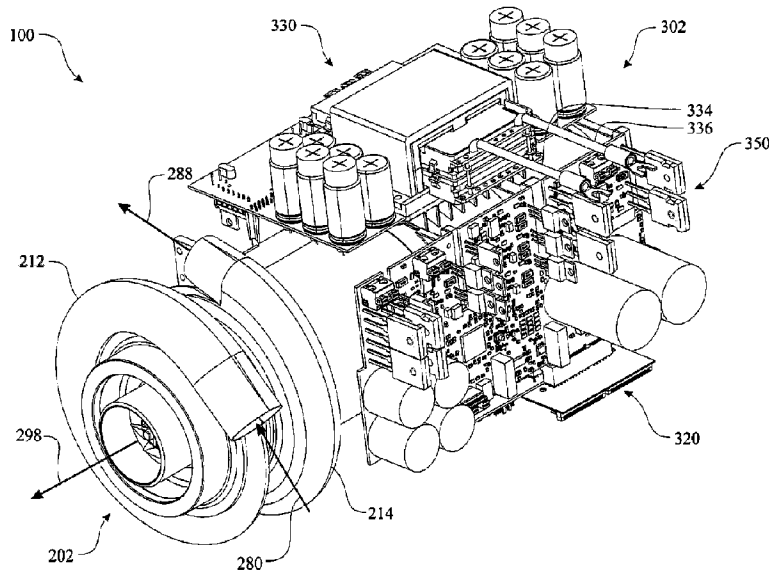
(51) Cl.Int./Int.Cl. *B81B 5/00* (2006.01),
F01D 15/00 (2006.01), *F01D 15/10* (2006.01),
H02K 7/18 (2006.01)

(71) Demandeur/Applicant:
GALILEO TECHNOLOGIES CORPORATION, US

(72) Inventeur/Inventor:
DEL CAMPO, OSVALDO, AR

(74) Agent: ADE & COMPANY INC.

(54) Titre : **MICROTURBINE ET METHODE DE FABRICATION**
(54) Title: **MICROTURBINE AND METHOD OF MANUFACTURE**



(57) **Abrégé/Abstract:**

A microturbine comprising a turbine, a compressor, and an electric generator operating on a single shaft. The microturbine is designed segmenting the assembly into three subassemblies: a micro turbine engine subassembly, a turbine air sourcing housing subassembly, and a compressor air supply and electronics subassembly. The configuration enables efficient assembly, maintenance and repairs, as the operational components can be diagnosed at a high level and the subassembly can be exchanged quickly to optimize uptime. The micro turbine engine subassembly includes an integrated ceramic compressor and turbine assembly and a generator installed in a single unit that is slideably inserted within an interior of the turbine air sourcing housing subassembly. The compressor air supply and electronics subassembly is assembled to a respective end of the turbine air sourcing housing subassembly. The microturbine creates compressed air, heated air, and electrical power.

MICROTURBINE AND METHOD OF MANUFACTURE

ABSTRACT

A microturbine comprising a turbine, a compressor, and an electric generator operating on a single shaft. The microturbine is designed segmenting the assembly into three subassemblies: a micro turbine engine subassembly, a turbine air sourcing housing subassembly, and a compressor air supply and electronics subassembly. The configuration enables efficient assembly, maintenance and repairs, as the operational components can be diagnosed at a high level and the subassembly can be exchanged quickly to optimize uptime. The micro turbine engine subassembly includes an integrated ceramic compressor and turbine assembly and a generator installed in a single unit that is slideably inserted within an interior of the turbine air sourcing housing subassembly. The compressor air supply and electronics subassembly is assembled to a respective end of the turbine air sourcing housing subassembly. The microturbine creates compressed air, heated air, and electrical power.

MICROTURBINE AND METHOD OF MANUFACTURE

FIELD OF THE INVENTION

[0001] The present invention relates generally to energy generating systems. More specifically, the present invention relates to a microscale energy cogeneration system having a design for improved assembly methods, where the microscale energy cogeneration system can be used in a variety of applications, including residential setting to supplement or substitute for a conventional utility electrical supply system and, further, can be used as part of an energy supply network. Even more particularly, the present invention is referred to as a distributed energy cogeneration method with which it is possible to generate electricity and heat water and air. The same module can be adapted for use in an electrically powered vehicle such as an automobile, a drone, and the like, an energy bank, or any other application.

DESCRIPTION OF RELATED ART

[0002] Micro Turbine engines are used to drive or rotate an electric power generator. It is desired that these power generating systems maintain maximum uptime. Reliability of these power generating systems is critical, as the applications of the power generating systems demand constant electrical output. When the power generating systems requires servicing or repairs, the down time needs to be minimized. The current Micro Turbine engine designs are complex and tedious to assemble, disassemble, service, repair, and/or reassemble. The complexity further impacts repair processes of the assembly, as the assembly processes and disassembly processes affects the longevity of downtime of the power generating system.

[0003] One key element of the Micro Turbine engines is the shaft and the associated blade assemblies. Each Micro Turbine engine includes a compressor blade assembly and a turbine blade assembly assembled to an engine shaft. Each of the blade assemblies is complex and needs to maintain reliability over extreme operating conditions, including temperature, speed (Revolutions per Minute (RPM's)), pressure, and the like. The extreme operating conditions

introduce immense stresses and strains on the blades, thus the quality of the blades is critical to maintain the required reliability of the blades during operation.

[0004] Cogeneration is a highly efficient means of generating heat and electric power at the same time from the same energy source. Displacing fossil fuel combustion with heat that would normally be wasted in the process of power generation reaches efficiencies that can triple, or even quadruple, conventional power generation. In general, cogeneration systems are adapted to generate both electricity and heat from a single energy source. Such a cogeneration system can recover exhaust gas heat or waste heat of cooling water generated from an engine or turbine during an electricity generation operation, so that the cogeneration system can achieve an increase in energy efficiency of 70 to 80% over other systems.

[0005] By virtue of such an advantage, the cogeneration system has recently been highlighted as an electricity and heat supply source for buildings. In particular, the cogeneration system exhibits highly-efficient energy utilization in that the recovered waste heat is mainly used to heat/cool a confined space and to heat water. Although cogeneration has been in use for nearly a century, in the mid-1980s relatively low natural gas prices made it a widely attractive alternative for new power generation. In fact, gas-fired cogeneration is largely responsible for the decline in conventional power plant construction that occurred in North America during the 1980s. Cogeneration accounted for a large proportion of all new power plant capacity built in North America during much of the period in the late 1980s and early 1990s.

[0006] Cogeneration equipment can be fired by fuels other than natural gas. There are installations in operation that use wood, agricultural waste, peat moss, and a wide variety of other fuels, depending on local availability.

[0007] The environmental implications of cogeneration stem not just from its inherent efficiency, but also from its decentralized character. Because it is impractical to transport heat over any distance, cogeneration equipment must be located physically close to its heat user. A number of environmentally positive consequences flow from this fact: power tends to be generated close to the power consumer, reducing transmission losses, stray current, and the need for distribution equipment significantly. Cogeneration plants tend to be built smaller, and to be

owned and operated by smaller and more localized companies than simple cycle power plants. As a general rule, they are also built closer to populated areas, which cause them to be held to higher environmental standards. In northern Europe, and increasingly in North America, cogeneration is at the heart of district heating and cooling systems. District heating combined with cogeneration has the potential to reduce human greenhouse gas emissions by more than any other technology except public transportation.

[0008] To understand cogeneration, it is necessary to know that most conventional power generation is based on burning a fuel to produce steam. It is the pressure of the steam which actually turns the turbines and generates power, in an inherently inefficient process. Because of a basic principle of physics, no more than one third of the energy of the original fuel can be converted to the steam pressure which generates electricity. Cogeneration, in contrast, makes use of the excess heat, usually in the form of relatively low-temperature steam exhausted from the power generation turbines. Such steam is suitable for a wide range of heating applications, and effectively displaces the combustion of carbon-based fuels, with all their environmental implications.

[0009] Today, existing electric generating technologies include large scale steam turbines producing electricity with a relatively low efficiency rate. The large scale steam turbines often emit undesirable byproducts, such as sulfur oxides, nitrous oxides, ashes, and mercury. Additionally, these large scale steam turbines release a large amount of heat, which is generally released into lakes often disrupting the environment.

[0010] More recently, it has been found that smaller scale turbines, such as micro-turbines, fueled by natural gas can operate with greater efficiency. During operation, the micro-turbines do not pollute to the same degree as large scale steam turbines and instead elements such as carbon dioxide and water are emitted, with only very low amounts of nitrogen oxides. Additionally, the heat recovery from operation of the micro-turbines is useful for heating water.

[0011] In many parts of the world there is a lack of electrical infrastructure. Installation of transmission and distribution lines to deliver the product to the consumer is very costly, especially in third world countries. Moreover, the electrical infrastructure in many countries is

antiquated and overworked, resulting in “brownouts” and “blackouts.” Consequently, there is a need for an energy generating system that can produce energy in a standalone system or that can be integrated into existing systems.

[0012] Even though there are several cogeneration systems in the market, all of them involve an important investment that makes this technology inaccessible for home owner users or portable applications. Also, it is very costly to escalate these types of systems, as the installation of several turbines together to supply a bigger demand or interconnecting a set of turbines for balancing out the generation of electricity in a determined area is not yet possible.

[0013] Assembly, maintenance, and repair costs are excessively high due to the designs of existing electric generating technologies. Currently offered electric generating technologies are complex and expensive to manufacture, maintain, and repair.

[0014] Therefore, even though the above cited technologies of the prior art address some of the energy generation needs of the market, a new, improved and economical microscale energy cogeneration system is still desired. It is desired to provide an electric generating technology that is designed for ease of assembly, maintenance and repair. It is also desired to provide an electric generating technology that is scalable.

BRIEF SUMMARY OF THE INVENTION

[0015] This invention is directed to a micro turbine assembly that can be used independently of a conventional utility electrical supply system or can be integrated into a conventional electrical supply system to supplement the system or contribute to the energy supply as part of a network.

[0016] In one aspect, the micro turbine assembly includes a turbine engine.

[0017] In a second aspect, the turbine engine comprises a turbine blade assembly secured to an engine shaft.

[0018] In another aspect, the turbine blade assembly comprises a series of ceramic blades.

[0019] In another aspect, the turbine blade assembly comprises a series of ceramic blades, wherein the turbine blade assembly is fabricated using a three-dimensional ceramic printing process.

[0020] In yet another aspect, the 3D printing process is accomplished by any suitable ceramic 3D printing process. The following is one example of a suitable ceramic 3D printing process:

Certain 3D Printing ceramics can be fueled with a special, ultra-fine alumina silica ceramic powder. To create ceramic prints, an industrial-grade printing technology is used. A 3D ceramic model is built one layer at a time, starting at the bottom. After the printer's rolling mechanism has spread a very thin layer of ceramic powder on a basis, a print head places organic binder at specified locations. This process is repeated until the 3D design is printed completely.

As with 'normal' ceramics, the model now has to be 'baked', so after the model has bathed in ultrafine powder, it is put into a drying oven to strengthen the material. The model will however still be fragile after this process and the state it is in afterwards is called the 'green state'.

Once dry, the excess powder is removed from the model and it is now ready to get fired in an oven to really gain some strength. At this point, a pre-glaze coating is applied, which is dried and then fired another time. The last step involves one more glazing and firing session so that the model gets a smooth and glossy coating in a multitude of possible colors.

[0021] In another aspect, the turbine blade assembly comprises a series of metal blades.

[0022] In another aspect, the turbine blade assembly comprises a series of metal blades, wherein the turbine blade assembly is fabricated using a three-dimensional metal printing process.

[0023] In yet another aspect, the 3D printing process is accomplished by any suitable metal 3D printing process. The following is one example of a suitable metal 3D printing process:

The 3D metal printing process is a multi-layered additive approach, just like other forms of 3D printing and requires the design to be sliced very finely on the horizontal plane before it can start to be built. The 3D metal printer receives instructions from a computer, instructing the Laser what shape to trace out across a vat of metal powder. The Laser then pulses and heats up the powder which subsequently creates a solid form of the object. This is how 3D printing in metal begins.

Once this initial base has been laid out, the 3D metal printing process begins again, adding each layer, which is typically no more than 0.1mm thick. This very gradual additive process enables metal 3D printers to create a final product, using heat from the Laser to form a solid shape from the powder. This process is known either as Direct Metal Laser Sintering (DMLS) or Selective Laser Melting (SLM), depending on the heat used and whether the powder is melted completely or just heated enough to fuse together.

Additional post processing can be employed to improve the grain structure of the final product.

[0024] In another aspect, the turbine blade assembly comprises a series of metallic blades, wherein the turbine blade assembly is fabricated using a three-dimensional printing process.

[0025] In yet another aspect, the turbine engine comprises a turbine blade assembly secured to a first portion of the engine shaft.

[0026] In yet another aspect, the turbine engine comprises a turbine blade assembly secured to a first end of the engine shaft.

[0027] In yet another aspect, the micro turbine assembly includes a compressor.

[0028] In yet another aspect, the turbine engine comprises a compressor blade assembly secured to the engine shaft.

[0029] In yet another aspect, the turbine engine comprises a compressor blade assembly provided on the engine shaft.

[0030] In another aspect, the compressor blade assembly comprises a series of ceramic blades.

[0031] In another aspect, the compressor blade assembly comprises a series of ceramic blades, wherein the compressor blade assembly is fabricated using a three-dimensional ceramic printing process.

[0032] In another aspect, the compressor blade assembly comprises a series of metal blades.

[0033] In another aspect, the compressor blade assembly comprises a series of metal blades, wherein the compressor blade assembly is fabricated using a three-dimensional metal printing process.

[0034] In yet another aspect, the turbine engine comprises a compressor blade assembly provided at a second portion of the engine shaft.

[0035] In yet another aspect, the turbine engine comprises a compressor blade assembly secured to the second portion of the engine shaft, where a gap is provided between the first portion of the engine shaft and the second portion of the engine shaft.

[0036] In yet another aspect, the turbine engine comprises a magnetic rotor secured to a third portion of the engine shaft.

[0037] In yet another aspect, the turbine engine comprises a magnetic rotor provided at a third portion of the engine shaft.

[0038] In yet another aspect, the turbine engine comprises a magnetic rotor shaft located between the magnetic rotor and the engine shaft.

[0039] In yet another aspect, the turbine engine comprises a magnetic rotor provided at the third portion of the engine shaft, where a gap is provided between the second portion of the engine shaft and the third portion of the engine shaft.

[0040] In yet another aspect, the second portion of the engine shaft is located between the first portion of the engine shaft and the third portion of the engine shaft.

[0041] In yet another aspect, a thrust bearing is integrally formed as a feature of the engine shaft.

[0042] In yet another aspect, the thrust bearing is assembled to the engine shaft.

[0043] In yet another aspect, the thrust bearing includes a first axial facing surface and a second axial facing surface.

[0044] In yet another aspect, the thrust bearing includes a first axial facing surface and a second axial facing surface, wherein at least one of the first axial facing surface and the second axial facing surface is planar, wherein the plane is substantially perpendicular to a rotational axis of the engine shaft.

[0045] In yet another aspect, the thrust bearing includes a first axial facing surface and a second axial facing surface, wherein each of the first axial facing surface and the second axial facing surface is planar, wherein the plane is substantially perpendicular to a rotational axis of the engine shaft.

[0046] In yet another aspect, a thrust bearing is located at a second end of the engine shaft, wherein the first end of the shaft and the second end of the shaft are opposite one another.

[0047] In yet another aspect, the thrust bearing is secured to a fourth portion of the engine shaft.

[0048] In yet another aspect, the thrust bearing is provided at the fourth portion of the engine shaft, where a gap is provided between the third portion of the engine shaft and the fourth portion of the engine shaft.

[0049] In yet another aspect, the third portion of the engine shaft is located between the second portion of the engine shaft and the fourth portion of the engine shaft.

[0050] In yet another aspect, the turbine blade assembly is assembled to the engine shaft by heating the turbine blade assembly and/or cooling the engine shaft, sliding the turbine blade assembly onto the engine shaft, and then cooling the entire assembly.

[0051] In yet another aspect, the compressor blade assembly is assembled to the engine shaft by heating the compressor blade assembly and/or cooling the engine shaft, sliding the compressor blade assembly onto the engine shaft, and then cooling the entire assembly.

[0052] In yet another aspect, the engine shaft further comprises a central bore extending centrally along a rotational axis of the engine shaft. The turbine blade assembly includes a frustum shaped surface concentric about a rotational axis of the turbine blade assembly, where the frustum or tapered shaped surface is contiguous with a central bore extending through the turbine blade assembly. The shaft includes a frustum or tapered surface having an angle or shape that is substantially the same as the frustum or tapered shaped surface of the turbine blade assembly. The frustum or tapered shaped surface of the turbine blade assembly is slideably assembled onto the frustum or tapered shaped surface of the engine shaft. An end cap can be employed to retain the turbine blade assembly on the engine shaft. The end cap applies a retention force, retaining the frustum or tapered shaped surface of the turbine blade assembly and the frustum or tapered shaped surface of the engine shaft against one another. The end cap can be assembled to an adjoining rod inserted into a bore formed in the engine shaft or onto a distal end of the engine shaft. When included, the adjoining rod can be secured within the bore of the engine shaft by an assembly locking bolt.

[0053] In yet another aspect, the adjoining rod can be formed to include a recession formed along an elongated central portion of the circumference of the adjoining rod. An insertion end is formed having a peripheral shape that slideably engages with the surface defining the bore formed in the engine shaft. A turbine end is formed having a peripheral shape that slideably engages with the surface defining the bore formed through the turbine blade assembly. The

recession extends between the peripheral shape of the insertion end and the peripheral shape of the turbine end.

[0054] In yet another aspect, the adjoining rod includes a through bore, wherein the assembly locking bolt is inserted through the through bore of the adjoining rod.

[0055] In yet another aspect, the turbine blade assembly includes a plurality of blades, wherein at least one blade of the plurality of blades includes an internal ray port passing therethrough.

[0056] In yet another aspect, the turbine blade assembly includes a plurality of blades, wherein each of two or more blades of the plurality of blades includes an internal ray port passing therethrough.

[0057] In yet another aspect, the turbine blade assembly includes a plurality of blades, wherein each of the blades of the plurality of blades includes an internal ray port passing therethrough.

[0058] In yet another aspect, the internal ray port passing through a respective blade of a plurality of blades of a turbine blade assembly has an inlet opening proximate an end having a wider diameter of the blade assembly and an outlet opening proximate an end having a narrower diameter of the blade assembly, wherein a size of the inlet opening is larger compared to a size of the outlet opening.

[0059] In yet another aspect, the internal ray port passing through a respective blade of a plurality of blades of a turbine blade assembly has an inlet opening proximate an end having a wider diameter of the blade assembly and an outlet opening proximate an end having a narrower diameter of the blade assembly, wherein the cross sectional size of the internal ray port gradually decreases as the internal ray port extends from the inlet opening to the outlet opening.

[0060] In yet another aspect, the internal ray port passing through a respective blade of a plurality of blades of a turbine blade assembly has an inlet opening proximate an end having a wider diameter of the blade assembly and an outlet opening proximate an end having a narrower

diameter of the blade assembly, wherein a center of the inlet opening is located radially outward of a center of the outlet opening.

[0061] In yet another aspect, the micro turbine assembly includes three distinct subassemblies.

[0062] In view of an assembly arrangement, the micro turbine assembly includes three distinct subassemblies, which includes: a micro turbine engine subassembly, a micro turbine air sourcing housing subassembly, and a compressor air supply and electronics subassembly.

[0063] In a second aspect, the micro turbine engine subassembly includes the engine shaft assembly, a compressor shroud, and a magnetic winding stator.

[0064] In another aspect, the micro turbine engine subassembly includes the engine shaft assembly, the compressor shroud, the magnetic winding stator, and an engine housing.

[0065] In yet another aspect, the micro turbine engine subassembly includes the engine shaft assembly, a combustion chamber, a turbine spacer, the compressor shroud, and the magnetic winding stator.

[0066] In yet another aspect, the micro turbine engine subassembly includes the engine shaft assembly, the combustion chamber, the turbine spacer, the compressor shroud, the magnetic winding stator, and the engine housing.

[0067] In yet another aspect, the micro turbine engine subassembly includes the engine shaft assembly, the combustion chamber, the turbine spacer, the compressor shroud, a first thrust bearing backing plate, a second thrust bearing backing plate, and the magnetic winding stator.

[0068] In yet another aspect, the micro turbine engine subassembly includes the engine shaft assembly, the combustion chamber, the turbine spacer, the compressor shroud, the first thrust bearing backing plate, the second thrust bearing backing plate, the magnetic winding stator, and the engine housing.

[0069] In yet another aspect, the micro turbine engine subassembly includes the engine shaft assembly, the combustion chamber, the turbine spacer, the compressor shroud, the first thrust bearing backing plate, the second thrust bearing backing plate, the magnetic winding stator, a motor stator spacer, and the heat sink body.

[0070] In yet another aspect, the micro turbine engine subassembly includes the engine shaft assembly, the combustion chamber, the turbine spacer, the compressor shroud, the first thrust bearing backing plate, the second thrust bearing backing plate, the magnetic winding stator, the motor stator spacer, the heat sink body, and the engine housing.

[0071] In yet another aspect, the micro turbine air sourcing housing subassembly includes a compressor exhaust scroll and an engine housing.

[0072] In yet another aspect, the micro turbine air sourcing housing subassembly includes a turbine air intake scroll, the compressor exhaust scroll, and the engine housing.

[0073] In yet another aspect, the micro turbine air sourcing housing subassembly includes the compressor exhaust scroll, a radial turbine shroud, and the engine housing.

[0074] In yet another aspect, the micro turbine air sourcing housing subassembly includes the turbine air intake scroll, the compressor exhaust scroll, the radial turbine shroud, and the engine housing.

[0075] In yet another aspect, the compressor air supply and electronics subassembly includes a compressor air supply housing.

[0076] In yet another aspect, the compressor air supply and electronics subassembly includes a compressor air supply housing assembly interface member affixed to the compressor air supply housing at an assembly end of the compressor air supply and electronics subassembly. A compressor air supply housing assembly airflow passageway is formed through the compressor air supply housing assembly interface member.

[0077] In yet another aspect, the compressor air supply and electronics subassembly includes a planar transformer and the compressor air supply housing.

[0078] In yet another aspect, the compressor air supply and electronics subassembly includes a multilevel inverter, the planar transformer and the compressor air supply housing.

[0079] In yet another aspect, the compressor air supply and electronics subassembly includes the multilevel inverter, power output cables, the planar transformer and the compressor air supply housing.

[0080] In yet another aspect, the compressor air supply and electronics subassembly includes a digital signal processor, the multilevel inverter, power output cables, the planar transformer and the compressor air supply housing.

[0081] In yet another aspect, the micro turbine assembly is assembled by inserting the micro turbine engine subassembly into the micro turbine air sourcing housing subassembly, and assembling the compressor air supply and electronics subassembly to the micro turbine air sourcing housing subassembly.

[0082] In yet another aspect, the micro turbine assembly is assembled by inserting the micro turbine engine subassembly into the micro turbine air sourcing housing subassembly at an assembly end of the micro turbine air sourcing housing subassembly towards a radial turbine shroud of the micro turbine air sourcing housing subassembly, and assembling the compressor air supply and electronics subassembly to the assembly end of the micro turbine air sourcing housing subassembly.

[0083] In yet another aspect, the micro turbine assembly is assembled by assembling the compressor air supply housing assembly interface member of the compressor air supply and electronics subassembly to the assembly end of the engine housing of the micro turbine air sourcing housing subassembly.

[0084] In yet another aspect, multiple micro turbine assemblies can be networked with one another forming a matrix to collectively supplying a single electrical output.

[0085] In yet another aspect, multiple micro turbine assemblies can be networked with one another forming a matrix to collectively supplying a single electrical output by inserting multiple micro turbine assemblies into an enclosure having multiple micro turbine assembly receptacles.

[0086] In yet another aspect, the enclosure having multiple micro turbine assembly receptacles further comprising a fuel supply manifold, wherein the fuel supply manifold is configured to transfer fuel from a fuel source to each micro turbine assembly receptacle of the multiple micro turbine assembly receptacles.

[0087] In yet another aspect, the fuel supply manifold includes a fuel supply coupler or connector at a distal end of the fuel supply manifold and a fuel delivery port located within each micro turbine assembly receptacle of the multiple micro turbine assembly receptacles.

[0088] In yet another aspect, the enclosure having multiple micro turbine assembly receptacles further comprising an exhaust collection manifold, wherein the exhaust collection manifold is configured to transfer exhaust from each micro turbine assembly receptacle of the multiple micro turbine assembly receptacles to an exhaust vent.

[0089] In yet another aspect, the exhaust collection manifold includes an exhaust discharge coupler or connector at a distal end of the exhaust collection manifold and an exhaust receiving port located within each micro turbine assembly receptacle of the multiple micro turbine assembly receptacles.

[0090] In yet another aspect, the enclosure having multiple micro turbine assembly receptacles further comprising an electrical power collection harness, wherein the electrical power collection harness is configured to transfer electric power generated by each micro turbine assembly located within each respective micro turbine assembly receptacle of the multiple micro turbine assembly receptacles to a series of system electrical output terminals for connectivity to an electrically powered device.

[0091] In yet another aspect, the exhaust collection manifold includes an exhaust discharge coupler or connector at a distal end of the exhaust collection manifold and an exhaust receiving

port located within each micro turbine assembly receptacle of the multiple micro turbine assembly receptacles.

[0092] In yet another aspect, the electric power generating bank can be integrated into a vehicle.

[0093] In yet another aspect, the electric power generating bank can be integrated into a land vehicle.

[0094] In yet another aspect, the electric power generating bank can be integrated into a land vehicle, wherein the land vehicle is an automobile, a race car, a truck, a motorcycle, a bicycle, a golf cart, a go-cart, a tractor, a farming vehicle, a construction vehicle, a front loader, a military vehicle, a crane, and the like.

[0095] In yet another aspect, the electric power generating bank comprising one or more micro turbine assembly receptacles can be integrated into lawn equipment, including a lawn mower, a leaf blower, an edger, a line trimmer, and the like; other low horsepower driven equipment including: a pressure washer, outdoor lighting, and the like.

[0096] This invention is directed to a microscale energy cogeneration system that can be used independently of a conventional utility electrical supply system or can be integrated into a conventional electrical supply system to supplement the system or contribute to the energy supply as part of a network.

[0097] In another form of the present invention, a microscale energy cogeneration method includes steps of converting the energy produced by the combustion chamber into mechanical energy and converting the mechanical energy produced by the turbine into electrical energy.

[0098] An important aspect of the present invention is a microscale energy cogeneration system designed to produce between 1 to 5 kWh, more particularly 1 to 3 kWh, and more specifically 3 kWh using a portable and modular unit.

[0099] It is an object of the present invention to provide a microscale energy cogeneration system that is capable of heating tap water and heating air at the same time with high efficiency.

[00100] In another aspect of the invention, the generator may be an electric generator producing alternating electric current during the operation of the microscale energy cogeneration system. The fuel for the microscale energy cogeneration system may be natural gas, diesel, gasoline, and liquefied petroleum gas (LPG), among others.

[00101] According to another aspect of the invention, the microscale energy cogeneration system further includes an exhaust passage downstream from the micro/nano-turbine delivering high temperature exhaust air from the micro/nano-turbine and a heat exchanger receiving the high temperature exhaust air for heat transfer. A water heating system for converting tap water into hot water may be coupled to a heat exchange exhaust for releasing lower temperature exhaust air. The system is modular and portable and is able to generate electricity, hot water and hot air at the same time with efficiency higher than 85%.

[00102] In yet another aspect of the invention, the microscale energy cogeneration system may include another heat exchanger for coupling the present system to the heating system of a house.

[00103] In yet another aspect of the invention, the microscale energy cogeneration system may be scaled up to form a set of interconnected micro/nano-turbines that can be used to provide the same user with more energy or to balance out the energy demand of a group of houses in a residential area.

[00104] In another aspect of the invention, the microscale energy cogeneration system may be portable or may be compatible for integration with a plurality of energy systems to provide the electrical distribution system with power and further may be configured for integration into a heating system, a cooling system and/or a water heating system.

[00105] Another aspect of the present invention provides a microscale energy cogeneration system that creates an energy source that produces efficient and clean electric energy, produces heat for heating, produces hot water, does not create pollution or vibrations, and does not need any maintenance over the years.

[00106] Also another aspect of this invention comprises a microscale energy cogeneration system that is smart, modular and portable, which can be managed remotely through Internet.

[00107] Also another aspect of this invention comprises a microscale energy cogeneration system that has a 3 kWh, 110/220 V AC, 12/24 VDC output, using different fuels including natural gas, diesel, gasoline and LPG.

[00108] Also another aspect of this invention consists of a microscale energy cogeneration system that generates electricity, 700 liters of hot water per hour, and hot air for heating a building.

[00109] In summary, the present invention is related to a microscale energy cogeneration method comprising the steps of:

(a) at least a micro/nano-turbine set for converting fuel into mechanical energy, and a generator for converting mechanical energy produced by the micro/nano-turbine into electrical energy in the range of 1 to 5 kWh; further comprising an exhaust passage downstream from the micro/nano-turbine delivering high temperature exhaust air from the micro/nano-turbine; and

(b) at least one heat exchanger receiving high temperature exhaust air from the exhaust passage for heat transfer; the heat exchanger may be used to heat water and/or air of a house; a water heating system may be coupled to the heat exchanger for converting tap water into hot water and/or cool heating air into hot air. The portable micro/nano-turbine set may be scaled up by interconnecting several units at the same time and/or interconnecting different units of different users for balancing out the energy demand of those users.

[00110] Also, the present invention is related to a microscale energy cogeneration system comprising at least a micro/nano-turbine set and a generator set; an exhaust passage downstream from the micro/nano-turbine delivers high temperature exhaust air from the micro/nano-turbine; and at least one heat exchanger receiving high temperature exhaust air from the exhaust passage for heat transfer.

[00111] Also the present invention is related to a microscale distributed energy cogeneration method comprising the steps of:

- (a) Connecting a fuel provider to a micro/nano-turbine,
- (b) Connecting the micro/nano-turbine to a micro electric generator;
- (c) Connecting the micro electric generator to the electrical grid of a facility.
- (d) Connecting a heat exchanger apparatus to an exhaust passage downstream from the micro/nano-turbine, and
- (e) Connecting the heating system of the house to the heat exchanger apparatus.

[00112] These and other aspects, features, and advantages of the present invention will become more readily apparent from the attached drawings and the detailed description of the preferred embodiments, which follow.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[00113] The preferred embodiments of the invention will hereinafter be described in conjunction with the appended drawings provided to illustrate and not to limit the invention, where like designations denote like elements, and in which:

[00114] FIG. 1 presents a front, first side isometric view of an exemplary micro/nano-turbine driven energy generating system in accordance with the present invention;

[00115] FIG. 2 presents a front, first side isometric view of the exemplary micro/nano-turbine driven energy generating system, originally introduced in FIG. 1;

[00116] FIG. 3 presents a front elevation view of the exemplary micro/nano-turbine driven energy generating system, originally introduced in FIG. 1;

[00117] FIG. 4 presents a sectioned exploded assembly side elevation view of the exemplary micro/nano-turbine driven energy generating system, originally introduced in FIG. 1, the illustration presenting three distinct subassemblies;

[00118] FIG. 5 presents a sectioned side elevation view of an exemplary micro turbine air sourcing housing subassembly of the exemplary micro/nano-turbine driven energy generating system, originally introduced in FIG. 1;

[00119] FIG. 6 presents a sectioned side elevation view of an exemplary micro turbine engine subassembly of the exemplary micro/nano-turbine driven energy generating system, originally introduced in FIG. 1;

[00120] FIG. 7 presents an exploded side isometric view of the exemplary micro turbine engine subassembly, originally introduced in FIG. 1, the illustration presenting three distinct subassemblies;

[00121] FIG. 8 presents a sectioned side elevation view of an exemplary compressor air supply and electronics subassembly of the exemplary micro/nano-turbine driven energy generating system, originally introduced in FIG. 1;

[00122] FIG. 9 presents a sectioned assembly side elevation view of the exemplary micro/nano-turbine driven energy generating system, originally introduced in FIG. 1, the illustration excluding sectioning of the electronic components,

[00123] FIG. 10 presents a sectioned assembly side elevation view of the exemplary micro/nano-turbine driven energy generating system, originally introduced in FIG. 1, the illustration including sectioning of the electronic components,

[00124] FIG. 11 presents a side, rear isometric view of a first exemplary engine shaft assembly, wherein the first exemplary engine shaft assembly includes ceramic components;

[00125] FIG. 12 presents a side elevation view of the first exemplary engine shaft assembly, originally introduced in FIG. 11;

[00126] FIG. 13 presents a sectioned side elevation view of the first exemplary engine shaft assembly, originally introduced in FIG. 11;

[00127] FIG. 14 presents a side, rear isometric view of a second exemplary engine shaft assembly, wherein the second exemplary engine shaft assembly includes ceramic components;

[00128] FIG. 15 presents a side elevation view of the second exemplary engine shaft assembly, originally introduced in FIG. 14;

[00129] FIG. 16 presents a sectioned side elevation view of the second exemplary engine shaft assembly, originally introduced in FIG. 14;

[00130] FIG. 17 presents an exemplary schematic diagram illustrating an exemplary process for converting a mechanical motion into an electric power output;

[00131] FIG. 18 presents front, side perspective view of an exemplary micro/nano-turbine driven energy generating system in accordance with the present invention;

[00132] FIG. 19 presents a side elevation view of the micro/nano-turbine driven energy generating system, originally introduced in FIG. 18;

[00133] FIG. 20 presents a rear elevation view of the micro/nano-turbine driven energy generating system, originally introduced in FIG. 18;

[00134] FIG. 21 presents a top plan view of the micro/nano-turbine driven energy generating system, originally introduced in FIG. 18;

[00135] FIG. 22 presents a front elevation view of the micro/nano-turbine driven energy generating system, originally introduced in FIG. 18;

[00136] FIG. 23 presents an isometric view of the micro/nano-turbine driven energy generating system in combination with a water processing system and an air heating system installed within a household application through which tap water and/or air is heated using exhaust gases of the micro/nano-turbine;

CLAIMS

What is claimed is:

1. A micro turbine assembly (100) comprising:

a micro turbine engine subassembly (102), including:

engine shaft assembly (400, 500), a compressor shroud (120), and a magnetic winding stator (150) portion of a generator;

a micro turbine air sourcing housing subassembly (202), including:

an engine housing (210) and at least one of a turbine air intake scroll (212), and a compressor exhaust scroll (214); and

a compressor air supply and electronics subassembly (302), including:

compressor air supply housing (310),

a digital signal processor (320) assembled to the compressor air supply housing (310),

a planar transformer (330) assembled to the compressor air supply housing (310),
and

a multilevel inverter (340) assembled to the compressor air supply housing (310);

wherein the micro turbine engine subassembly (102) is designed as a compact subassembly having a diameter and shape enabling slideable insertion into an interior (211) of the micro turbine air sourcing housing subassembly (202),

wherein the micro turbine engine subassembly (102) is inserted into the interior (211) of the a micro turbine air sourcing housing subassembly (202), when assembled, the compressor shroud (120) is in fluid communication with the compressor exhaust scroll (214),

wherein the compressor air supply and electronics subassembly (302) is assembled to a compressor air supply end of the micro turbine air sourcing housing subassembly (102).

2. The micro turbine assembly (100) as recited in claim 1, wherein the digital signal processor (320) is assembled to an exterior surface of the compressor air supply housing (310),

wherein the planar transformer (330) is assembled to the exterior surface of the compressor air supply housing (310), and

wherein the multilevel inverter (340) is assembled to the exterior surface of the compressor air supply housing (310).

3. The micro turbine assembly (100) as recited in claim 1, wherein the micro turbine air sourcing housing subassembly (202) includes the engine housing (110), the turbine air intake scroll (212), and the compressor exhaust scroll (214).

4. The micro turbine assembly (100) as recited in claim 1, the engine shaft assembly (400, 500) further comprising:

a turbine and compressor shaft (410, 510);

a turbine (420, 520) assembled to the turbine and compressor shaft (410, 510);

a compressor (430, 530) assembled to the turbine and compressor shaft (410, 510); and

a magnetic rotor (450, 550) portion of a generator assembled to the turbine and compressor shaft (410, 510).

5. The micro turbine assembly (100) as recited in claim 5, wherein the turbine (420, 520) is fabricated of a ceramic material.

6. The micro turbine assembly (100) as recited in claim 5, wherein the turbine (420, 520) is fabricated of a metallic material.

7. The micro turbine assembly (100) as recited in claim 1, the engine shaft assembly (400, 500) further comprising:

a turbine and compressor shaft (410, 510);

a turbine (420, 520) assembled to the turbine and compressor shaft (410, 510);

a compressor (430, 530) assembled to the turbine and compressor shaft (410, 510);

a magnetic rotor (450, 550) portion of a generator assembled to the turbine and compressor shaft (410, 510), and

a spacer thrust bearing (440, 540) comprising a first axial facing surface (442, 542) and a bearing second axial facing surface (444, 544), the first axial facing surface (442, 542) and the second axial facing surface (444, 544) facing opposite directions.

8. The micro turbine assembly (100) as recited in claim 7, the micro turbine engine subassembly (102) further comprising:

a turbine spacer (110) located between the turbine (420, 520) and the compressor (430, 530).

9. The micro turbine assembly (100) as recited in claim 7, the micro turbine engine subassembly (102) further comprising:

a thrust foil bearing (140) assembled in axial registration with the spacer thrust bearing (440, 540)

a first backing plate thrust bearing (142) assembled in contact with a spacer thrust bearing first axial facing surface (442) of the spacer thrust bearing (440, 540), and

a second backing plate thrust bearing (144) assembled in contact with a spacer thrust bearing second axial facing surface (444) of the spacer thrust bearing (440, 540).

10. The micro turbine assembly (100) as recited in claim 7, the micro turbine engine subassembly (102) further comprising:

a heat sink body (160) assembled in axial registration with the magnetic winding stator (150).

11. A method of assembling a micro turbine assembly(100), the method comprising steps of:

assembling a micro turbine engine subassembly (102), the micro turbine engine subassembly (102) comprising:

an engine shaft assembly (400, 500),

a compressor shroud (120), and

a magnetic winding stator (150);

assembling a micro turbine air sourcing housing subassembly (202), the a micro turbine air sourcing housing subassembly (202) including:

an engine housing (210), and

at least one of a turbine air intake scroll (212) and a compressor exhaust scroll (214);

assembling a compressor air supply and electronics subassembly (302), including:

compressor air supply housing (310),

a digital signal processor (320) assembled to the compressor air supply housing,

a planar transformer (330) assembled to the compressor air supply housing, and

a multilevel inverter (340) assembled to the compressor air supply housing;

inserting the micro turbine engine subassembly (102) into an interior of the micro turbine air sourcing housing subassembly (202); and

assembling the compressor air supply and electronics subassembly (302) to a compressor airflow intake side of the engine housing (210).

12. The method of assembling a micro turbine assembly (100) as recited in claim 11, the step of assembling the compressor air supply and electronics subassembly (302) is accomplished by including steps of:

assembling the digital signal processor (320) to an exterior surface of the compressor air supply housing (310), and

assembling the planar transformer (330) to the exterior surface of the compressor air supply housing (310), and

assembling the multilevel inverter (340) to the exterior surface of the compressor air supply housing (310).

13. The method of assembling a micro turbine assembly (100) as recited in claim 11, the step of assembling the micro turbine air sourcing housing subassembly (202) includes a step of assembling at least one of the turbine air intake scroll (212) and the compressor exhaust scroll (214) to an exterior surface of the engine housing (210).

14. The method of assembling a micro turbine assembly(100) as recited in claim 11, the step of assembling the micro turbine air sourcing housing subassembly (202) includes a step of assembling each of the turbine air intake scroll (212) and the compressor exhaust scroll (214) to an exterior surface of the engine housing (210).

15. The method of assembling a micro turbine assembly (100) as recited in claim 11, further comprising a step of assembling the engine shaft assembly (400, 500), the method further comprising steps of:

assembling a magnetic rotor (450, 550) portion of a generator to a turbine and compressor shaft (410, 510);

assembling a compressor (430, 530) to the turbine and compressor shaft (410, 510); and

assembling a turbine (420, 520) to the turbine and compressor shaft (410, 510).

16. The method of assembling a micro turbine assembly (100) as recited in claim 15, the method further comprising a step of:

providing a spacer thrust bearing (440, 540) at an end of the turbine and compressor shaft (410, 510) opposite an end comprising the turbine (420, 520),

wherein the spacer thrust bearing (440, 540) includes a first axial facing surface (442, 542) and a bearing second axial facing surface (444, 544), the first axial facing surface (442, 542) and the second axial facing surface (444, 544) facing opposite directions.

17. The method of assembling a micro turbine assembly (100) as recited in claim 16, the step of assembling a micro turbine engine subassembly (102) further comprising steps of:

positioning a thrust foil bearing (140) in axial registration with the spacer thrust bearing (440, 540)

positioning a first backing plate thrust bearing (142) in contact with a spacer thrust bearing first axial facing surface (442) of the spacer thrust bearing (440, 540), and

positioning a second backing plate thrust bearing (144) in contact with a spacer thrust bearing second axial facing surface (444) of the spacer thrust bearing (440, 540).

18. The method of assembling a micro turbine assembly (100) as recited in claim 15, the method further comprising a step of:

locating a turbine spacer (110) between the turbine (420, 520) and the compressor (430, 530).

19. The method of assembling a micro turbine assembly (100) as recited in claim 15, wherein the turbine (420, 520) is fabricated of one of at least one of a ceramic material and a metallic material.

20. The method of assembling a micro turbine assembly (100) as recited in claim 11, further

comprising a step of:

positioning a heat sink body (160) in axial registration with the magnetic winding stator (150).

+

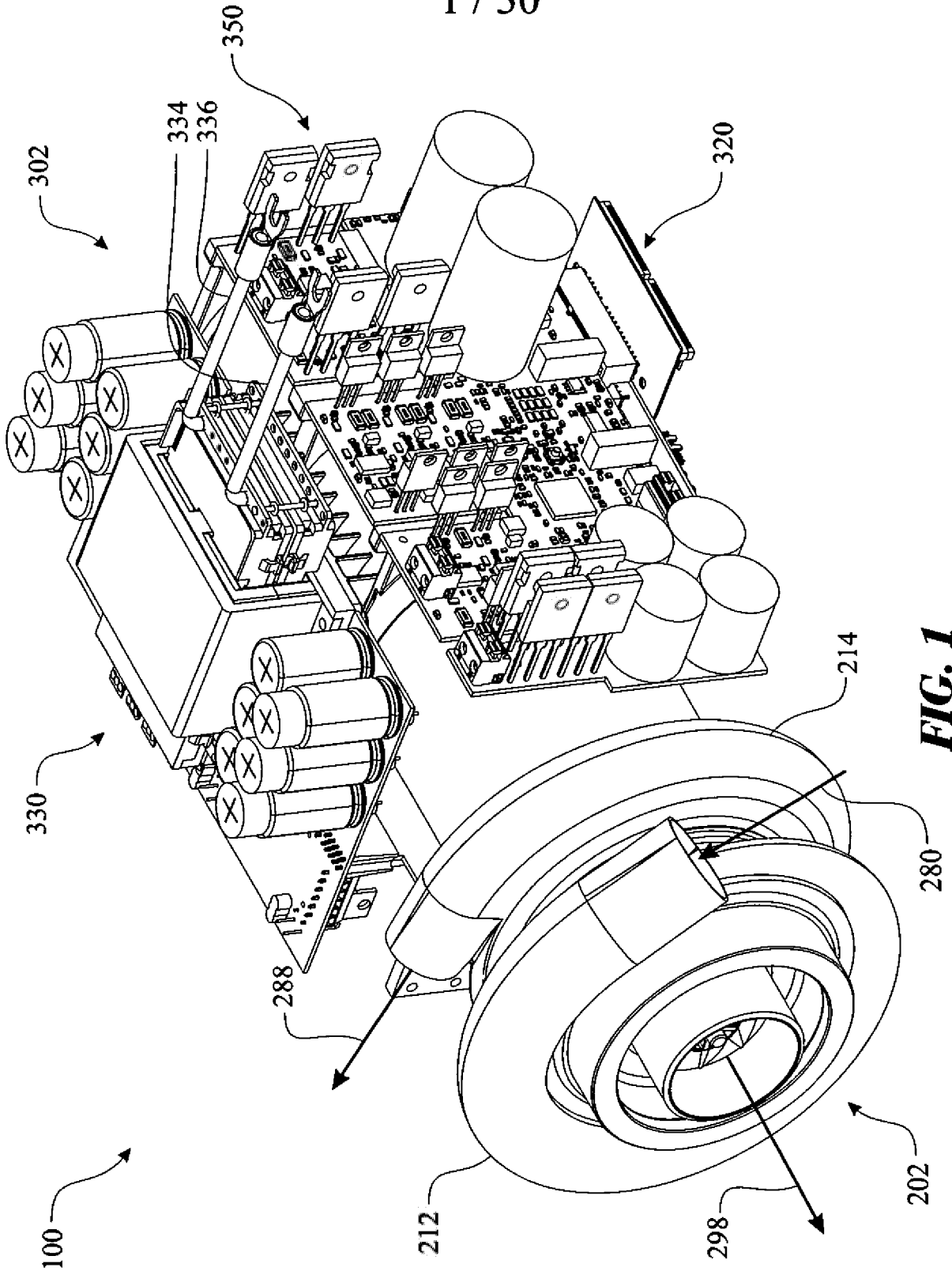


FIG. 1

+

+

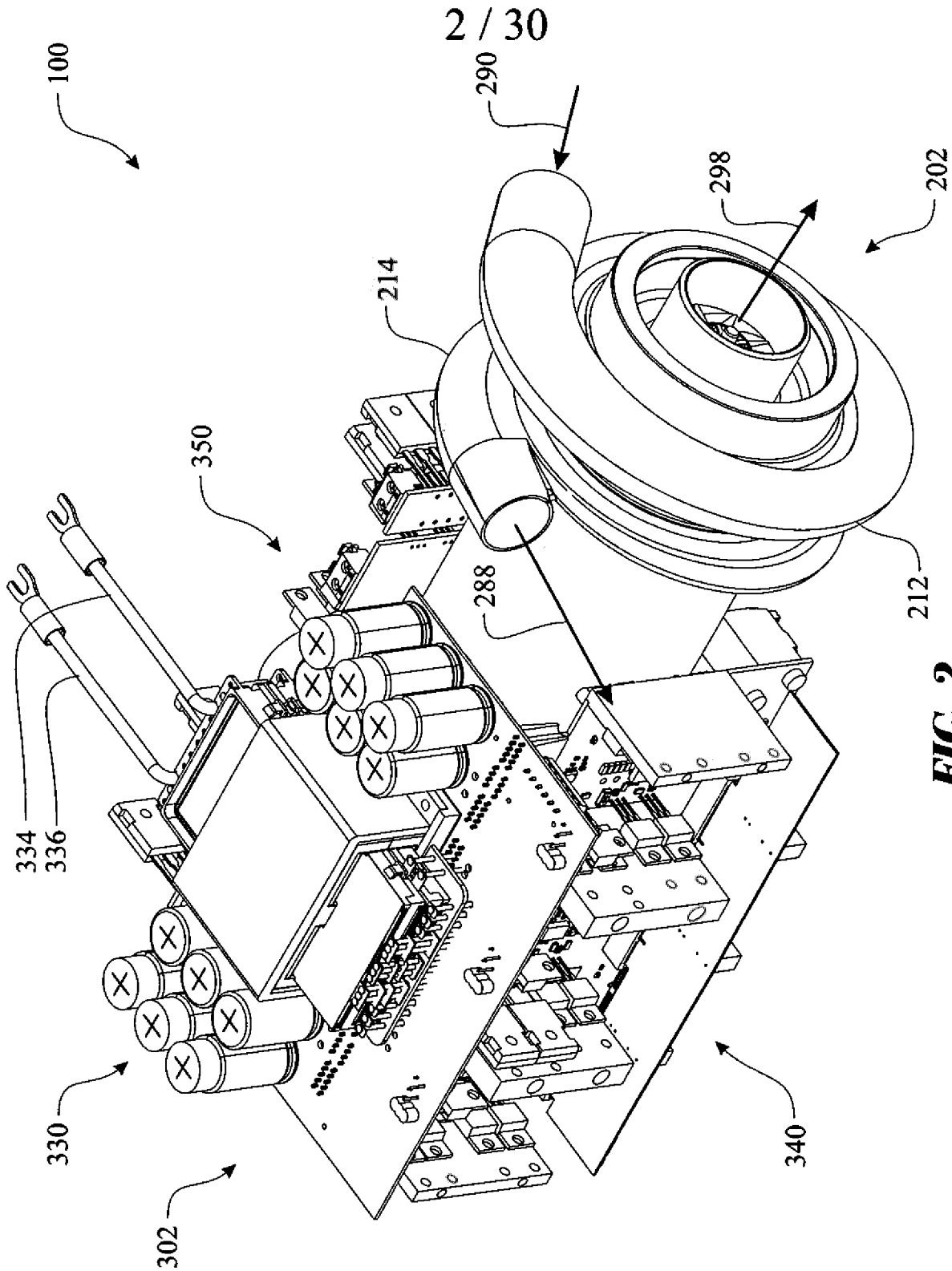


FIG. 2

+

+

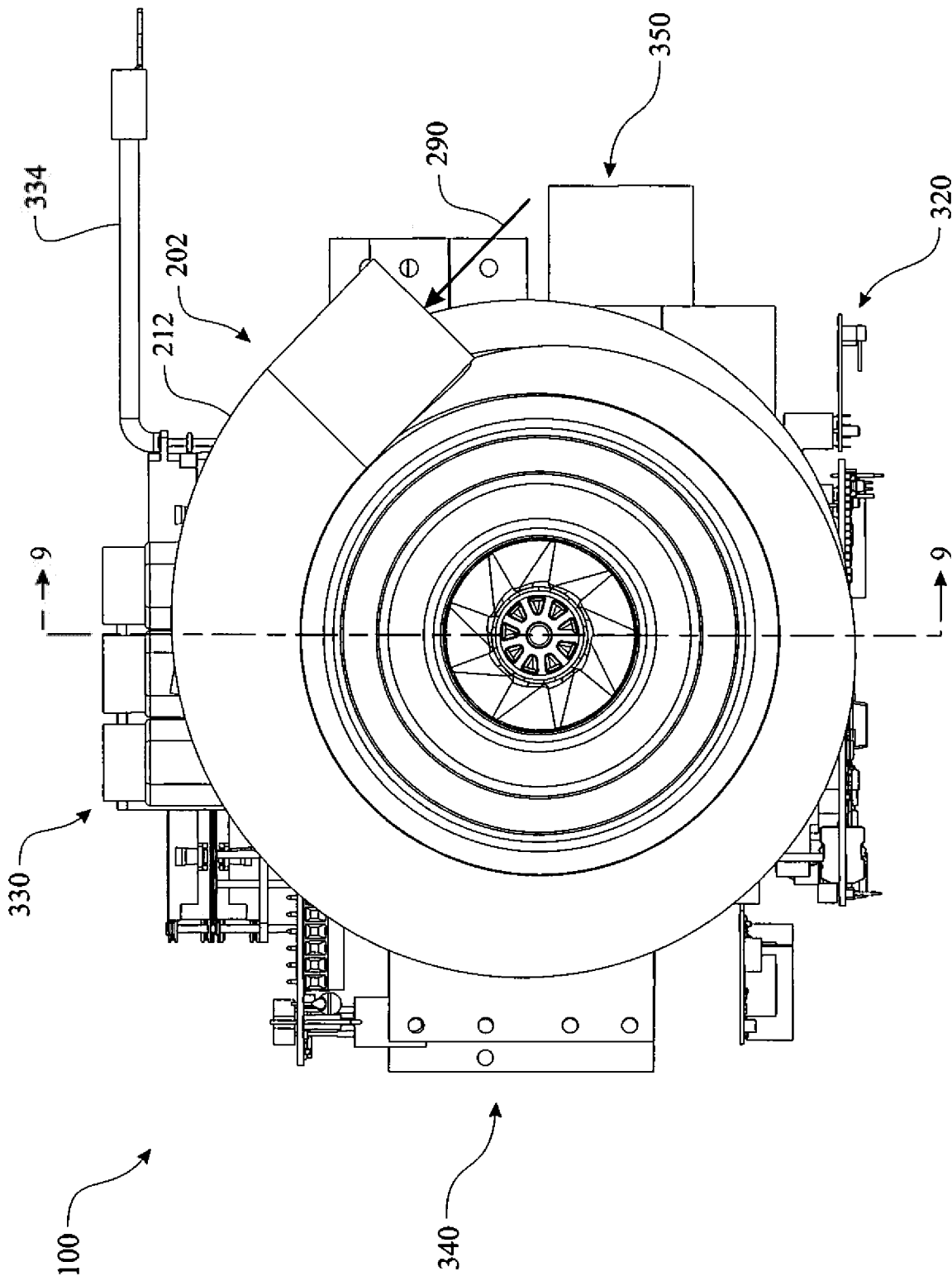


FIG. 3

+

+

4 / 30

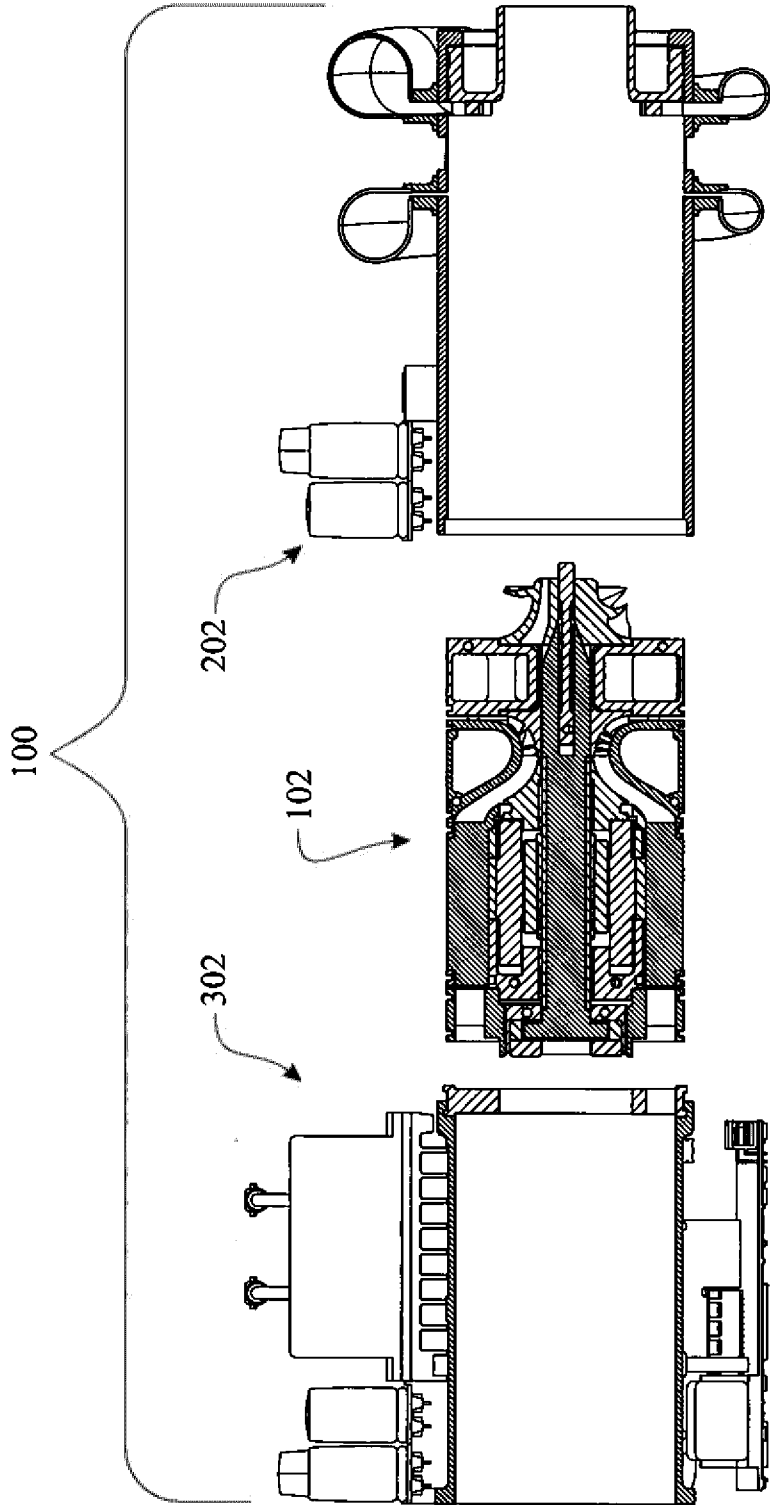


FIG. 4

+

+

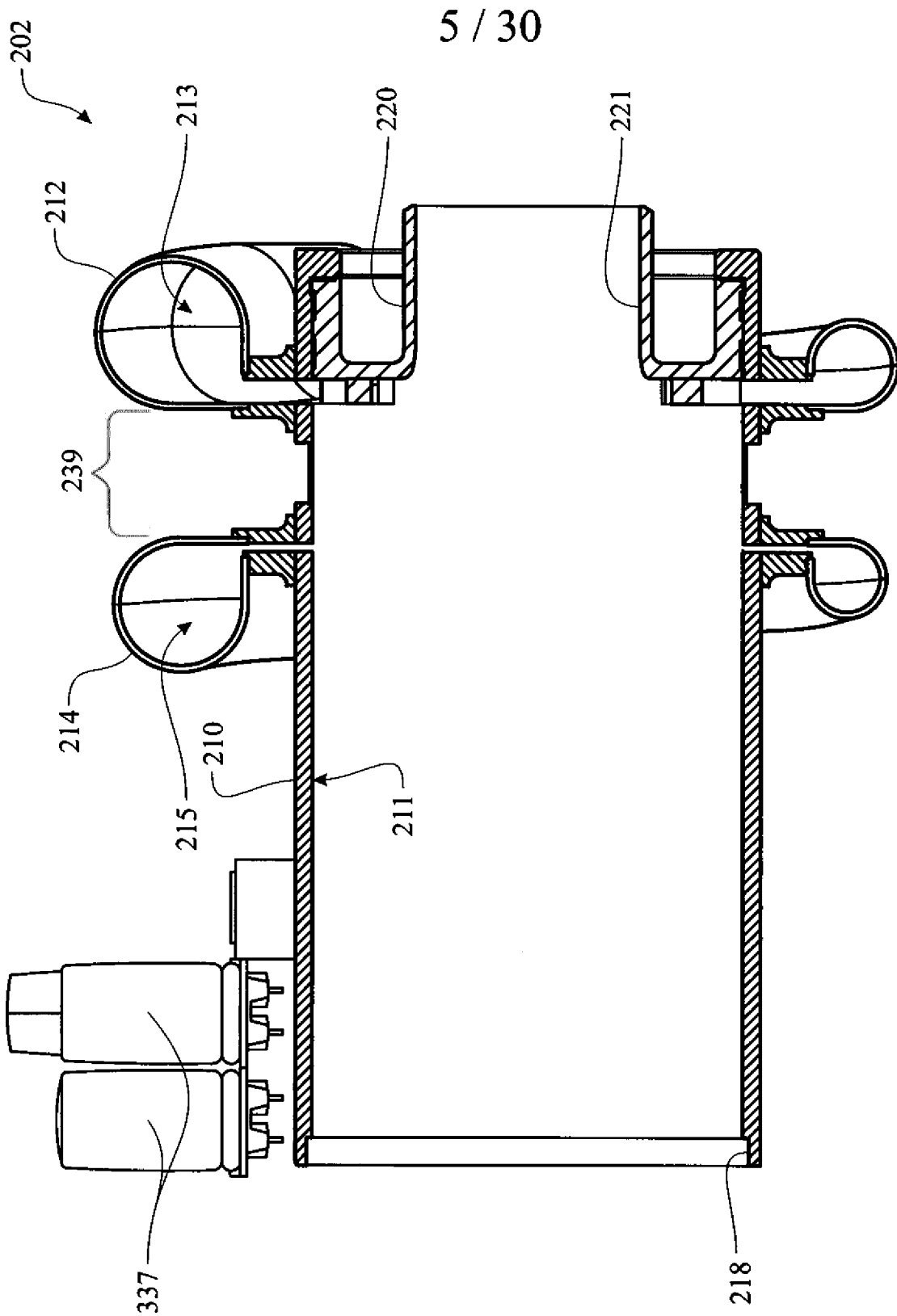


FIG. 5

+

+

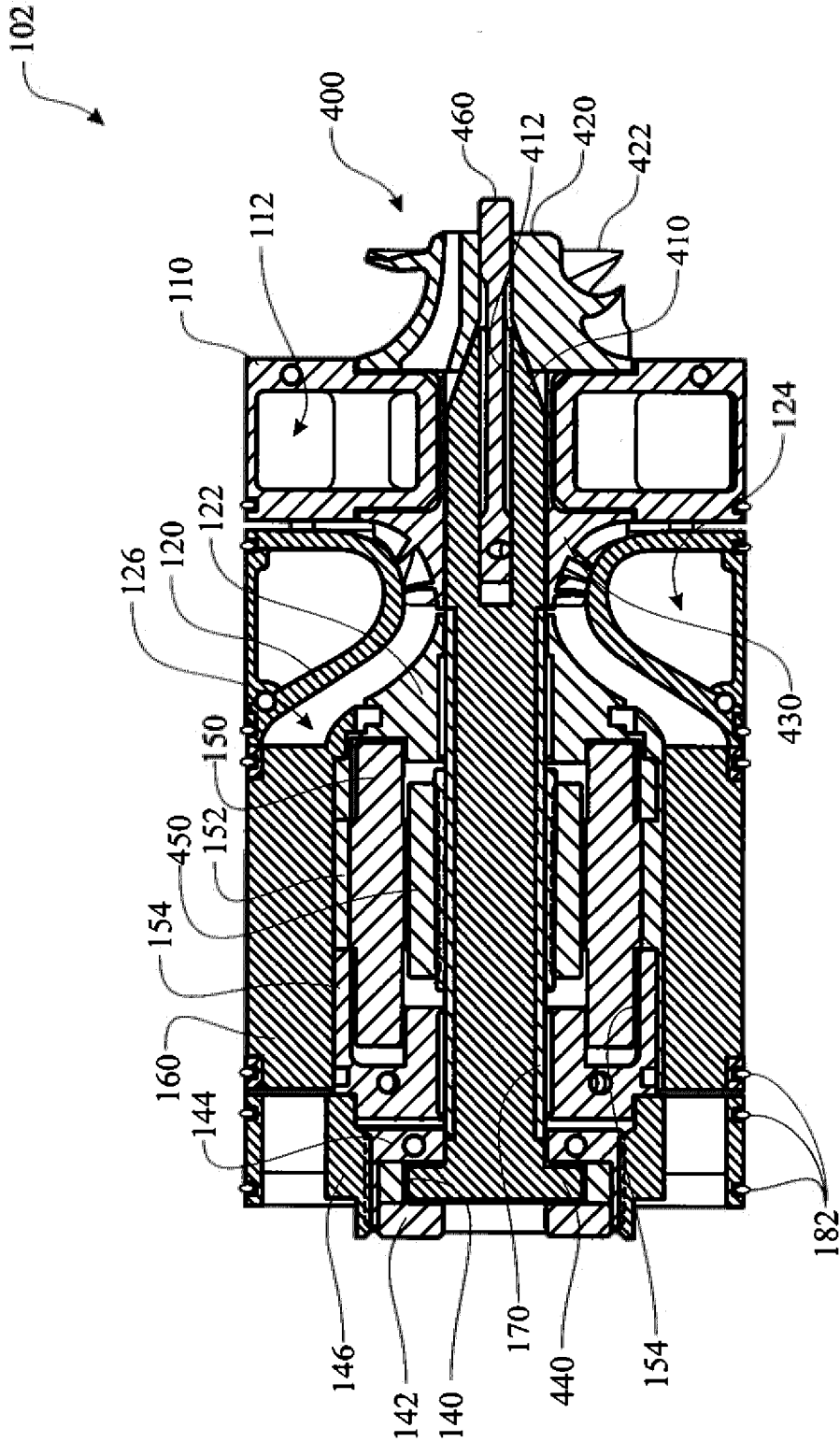


FIG. 6

+

+

7 / 30

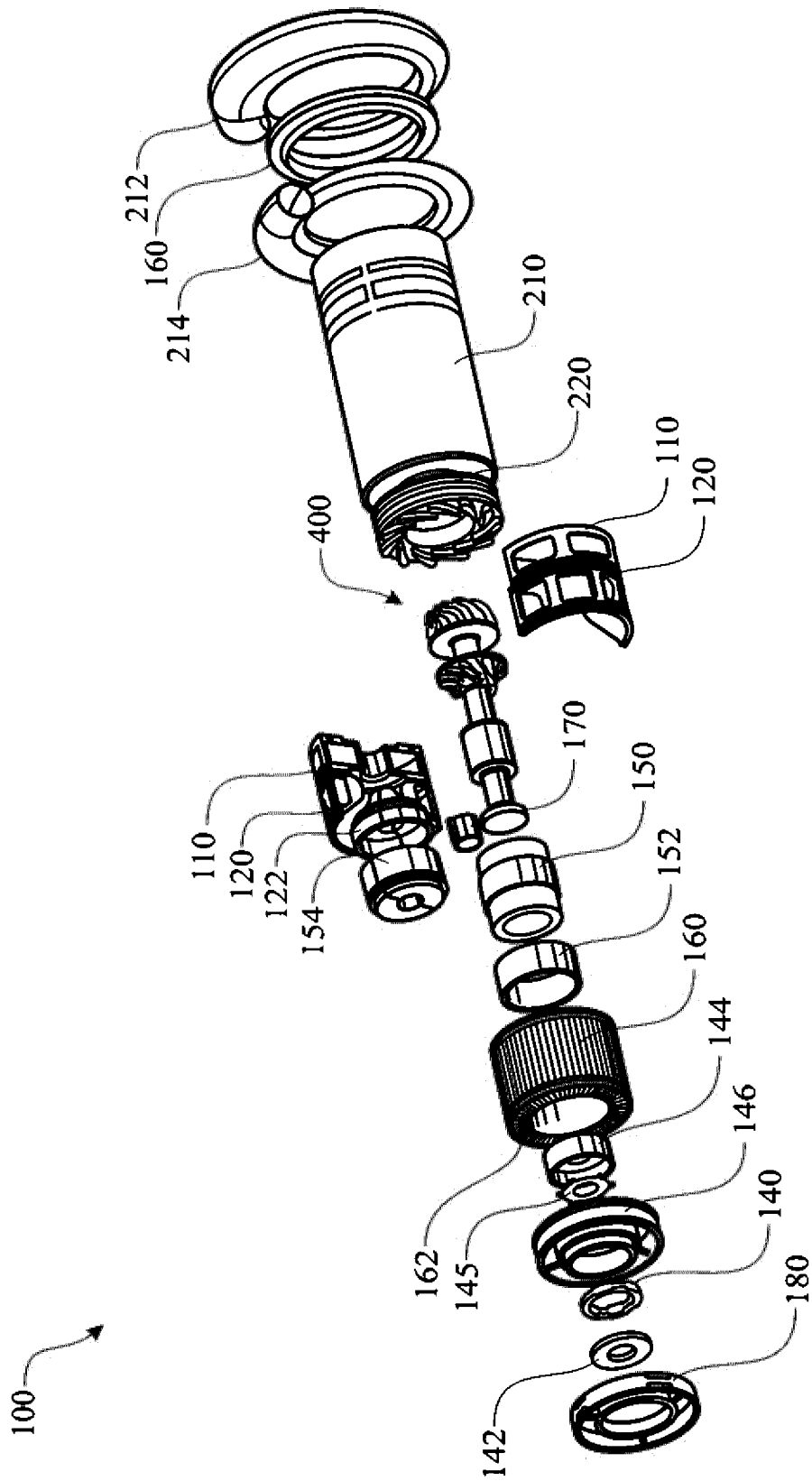


FIG. 7

+

+

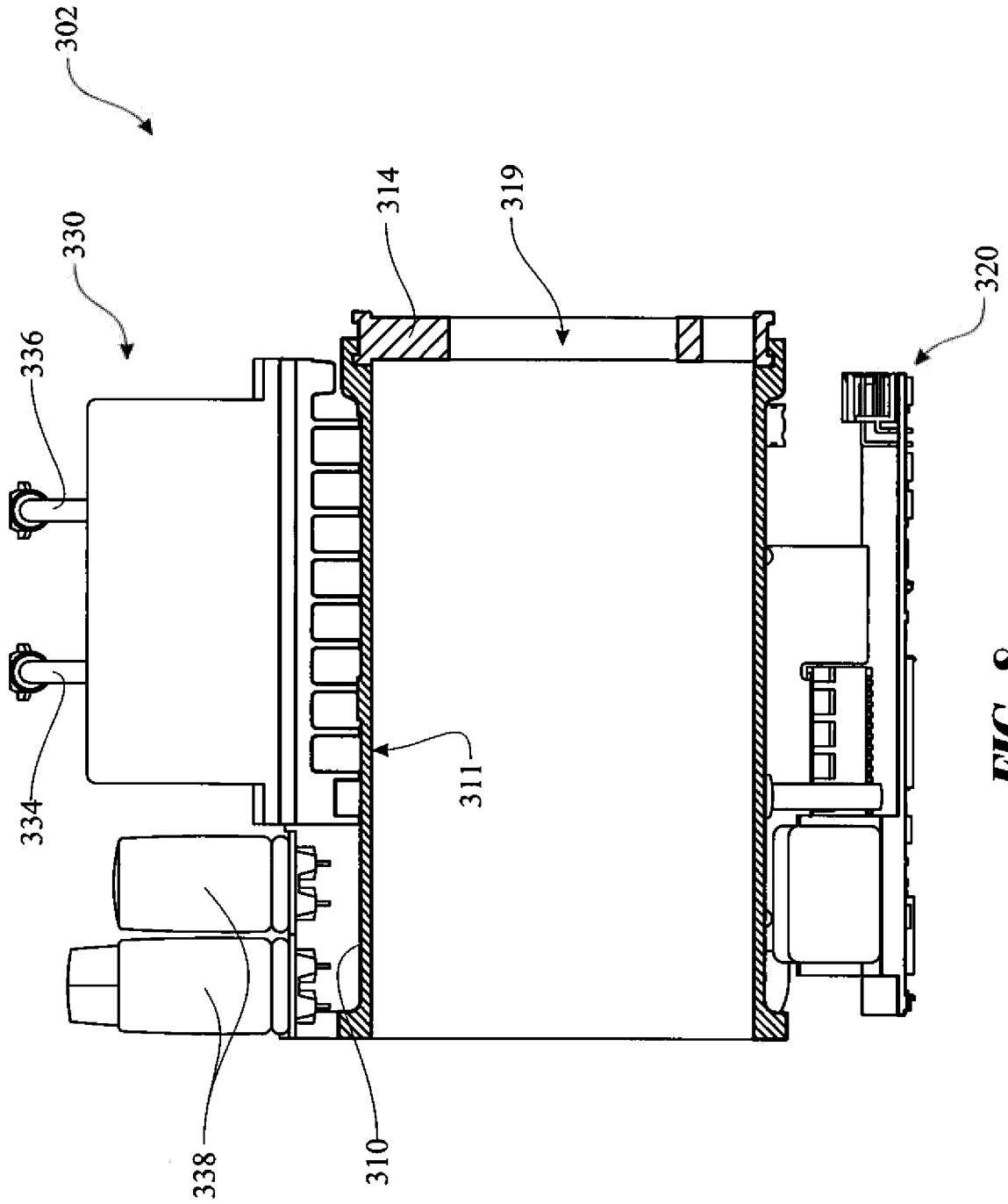


FIG. 8

+

+

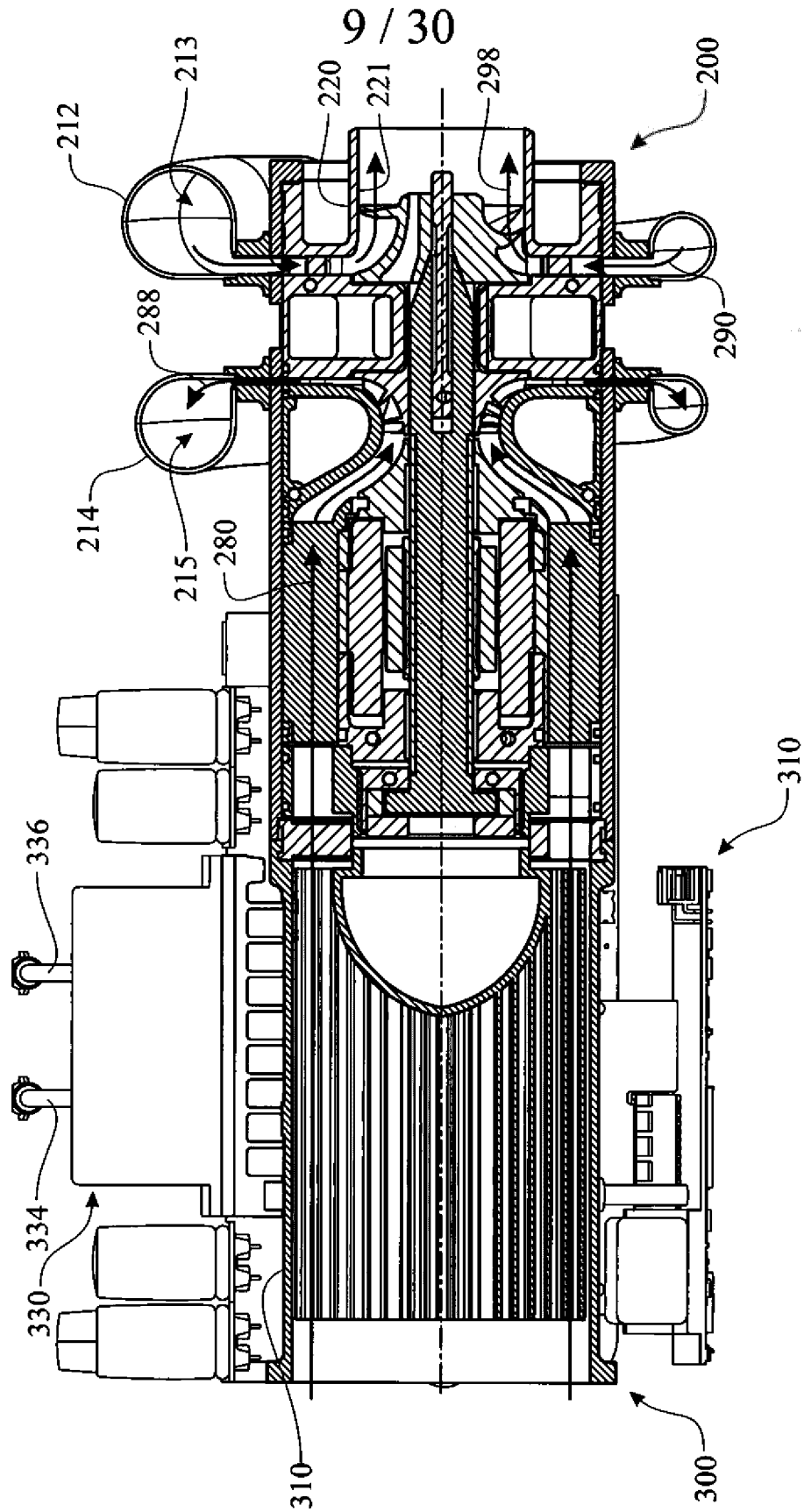


FIG. 9

+

+

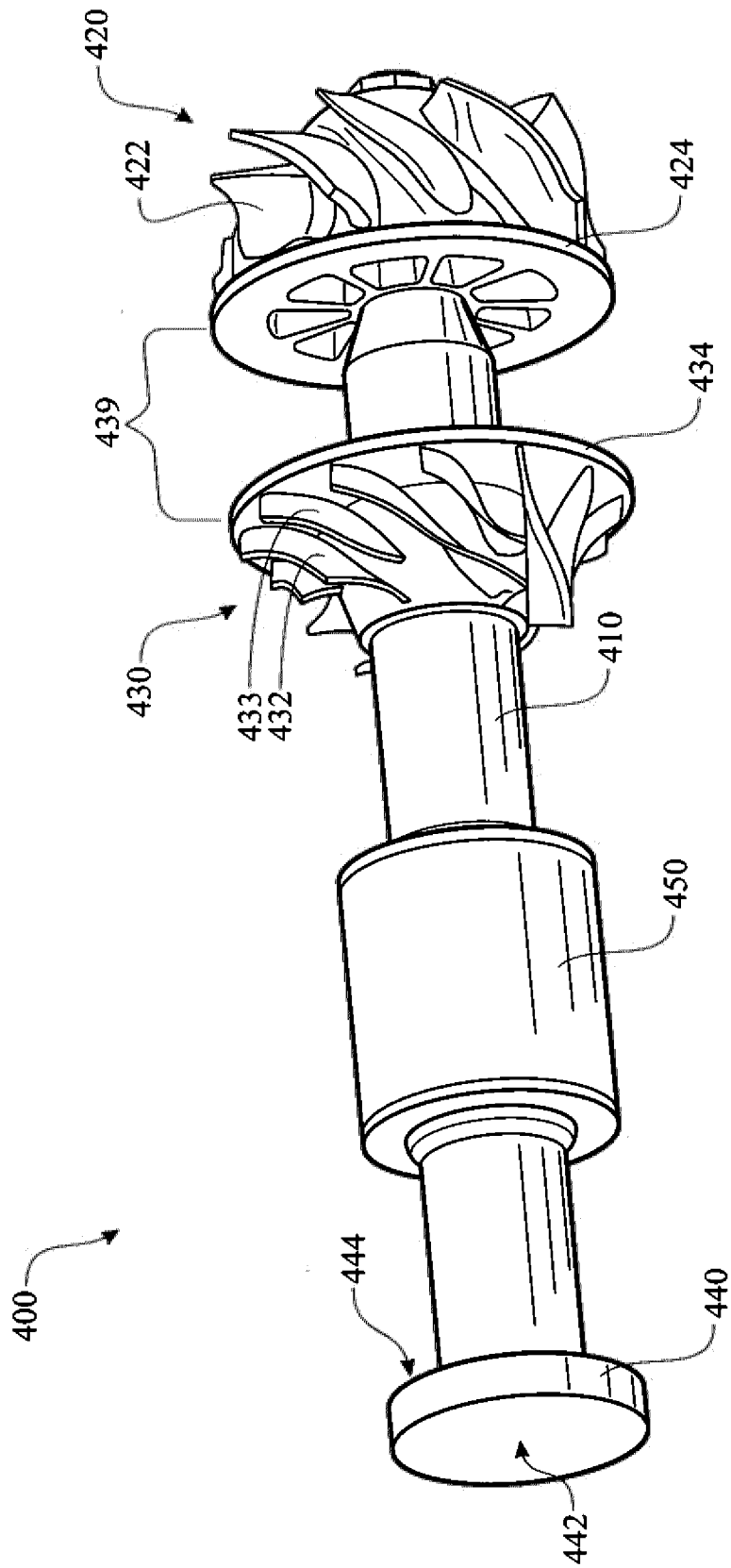


FIG. 11

+

+

12 / 30

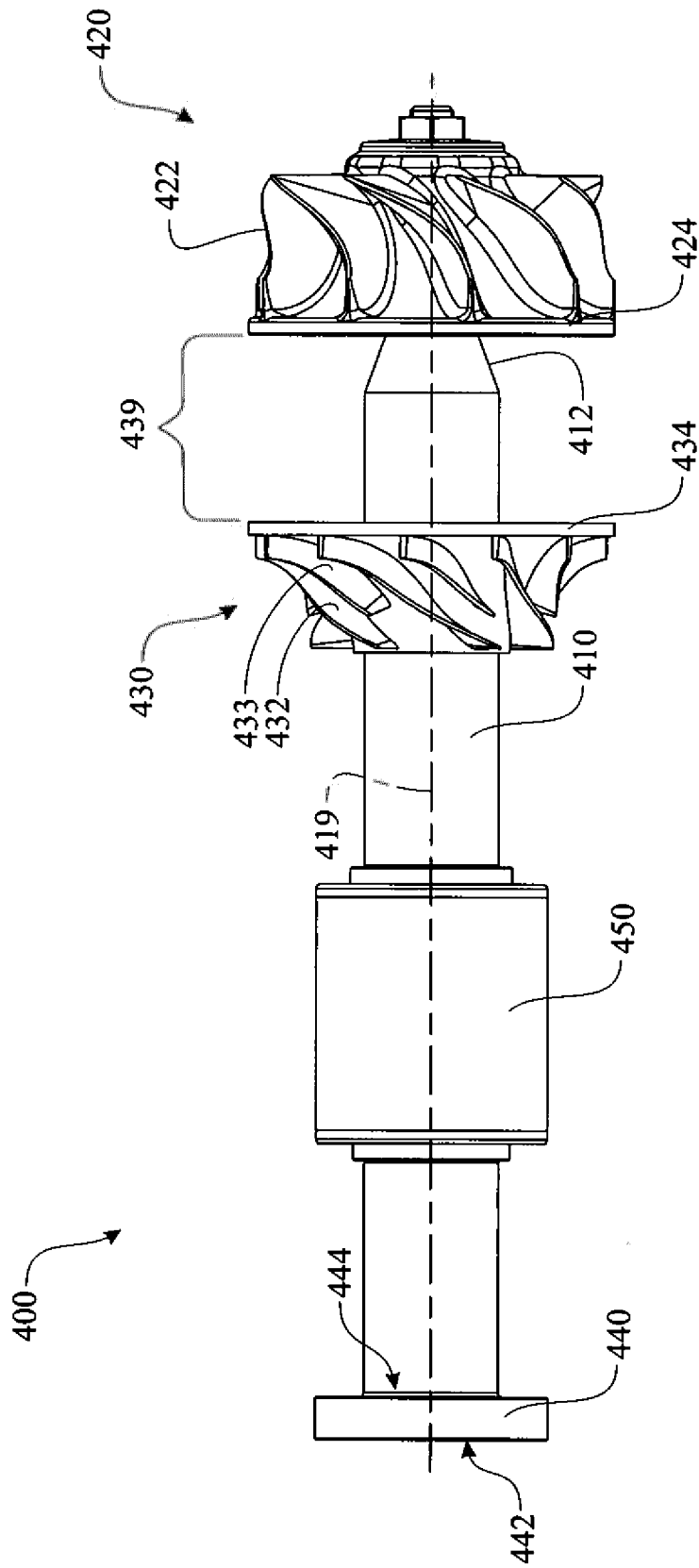


FIG. 12

+

+

13 / 30

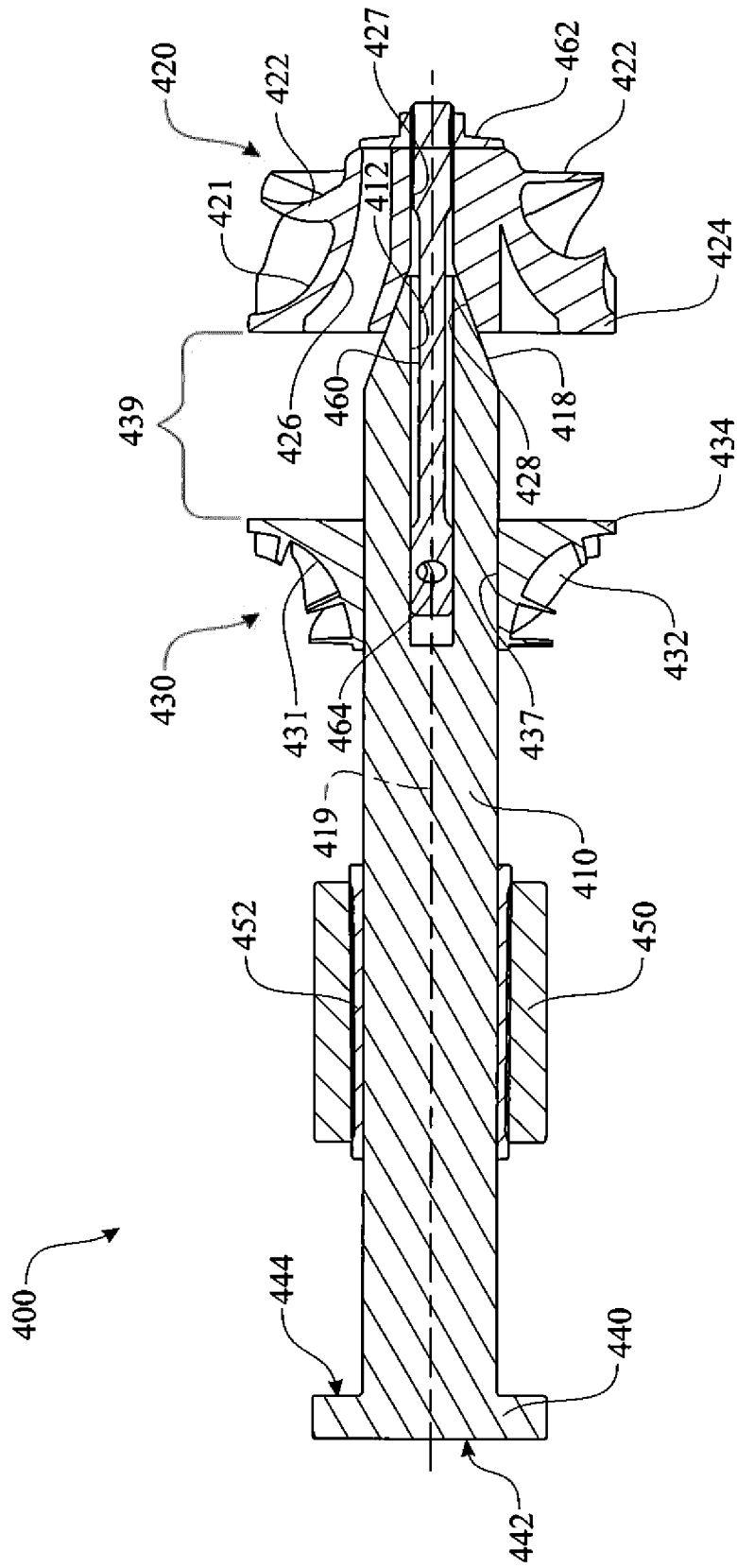


FIG. 13

+

+

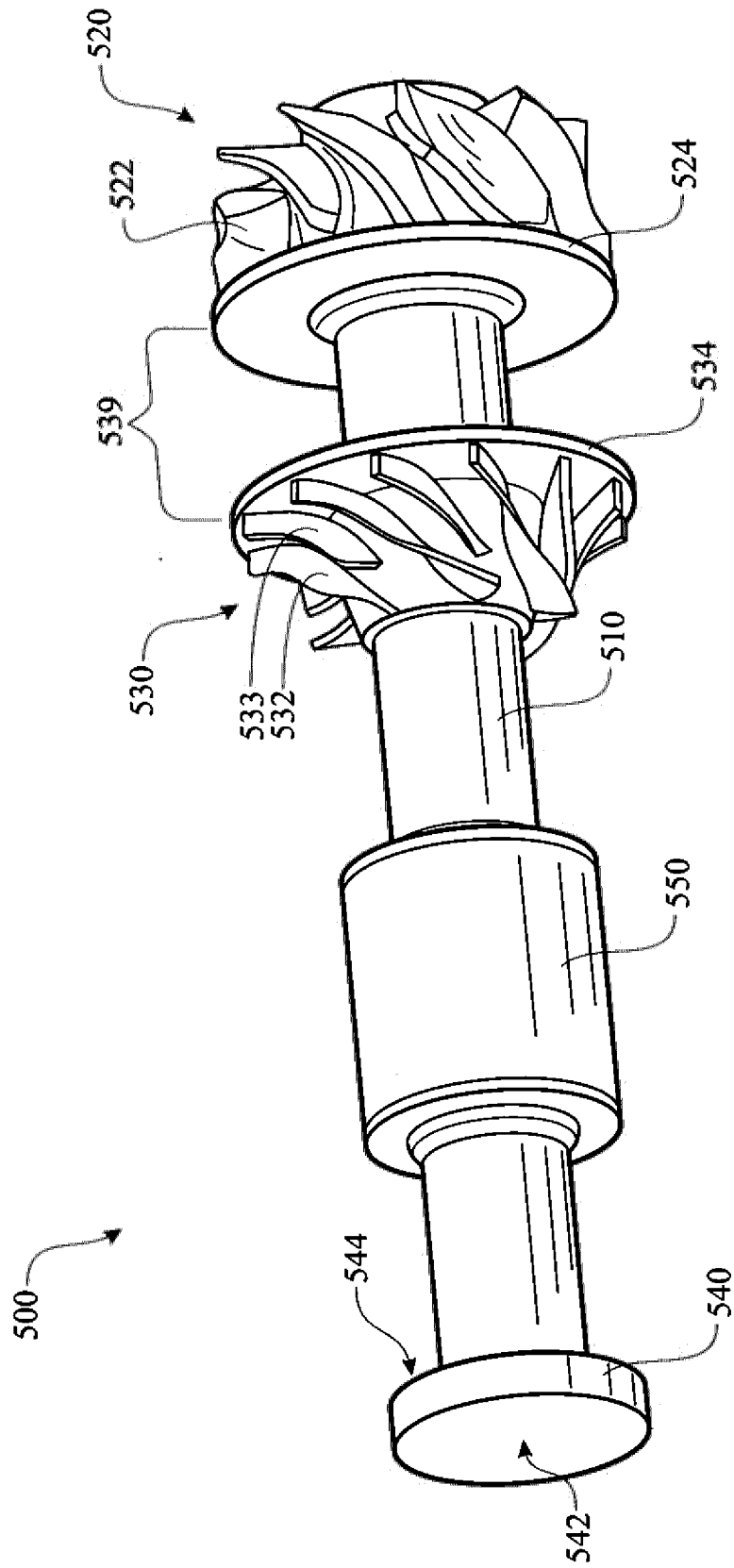


FIG. 14

+

+

15 / 30

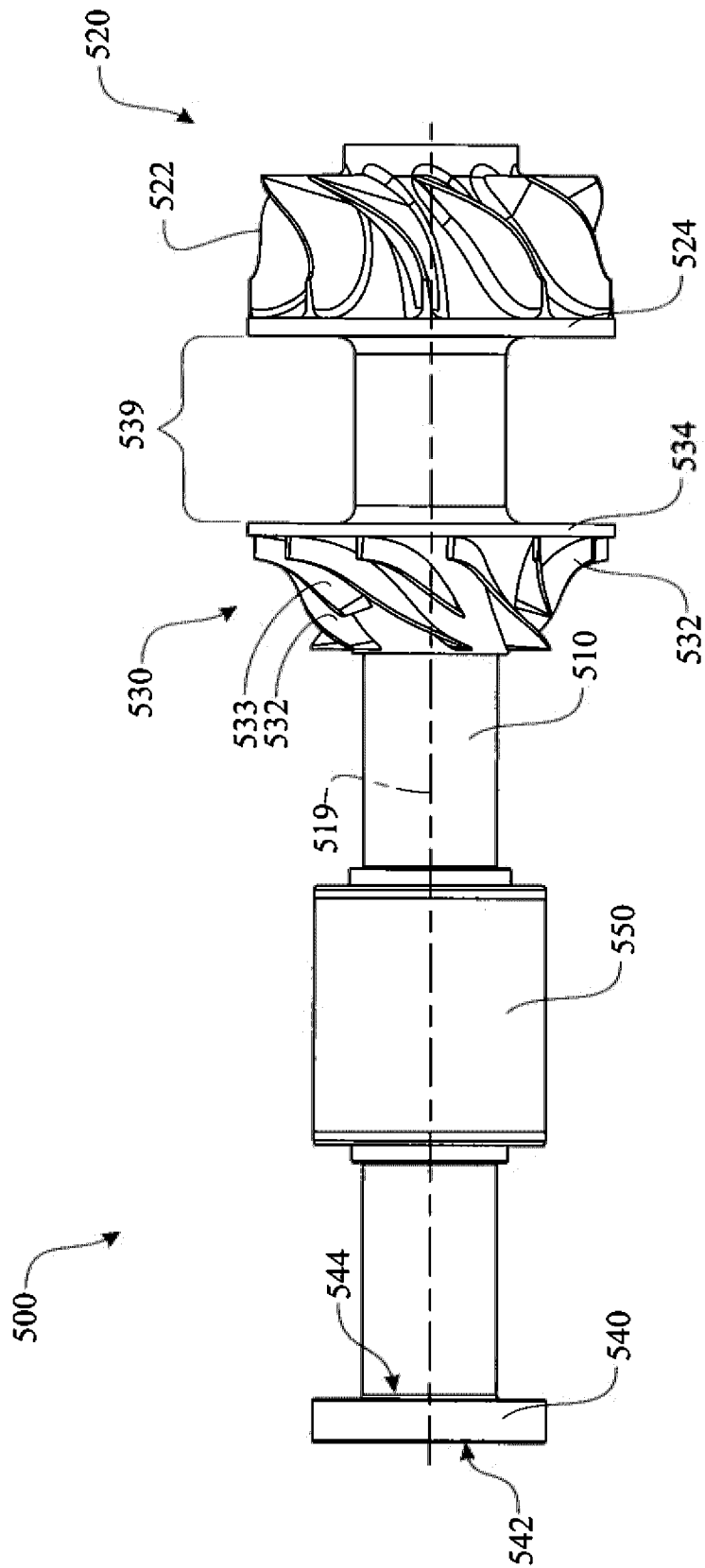


FIG. 15

+

+

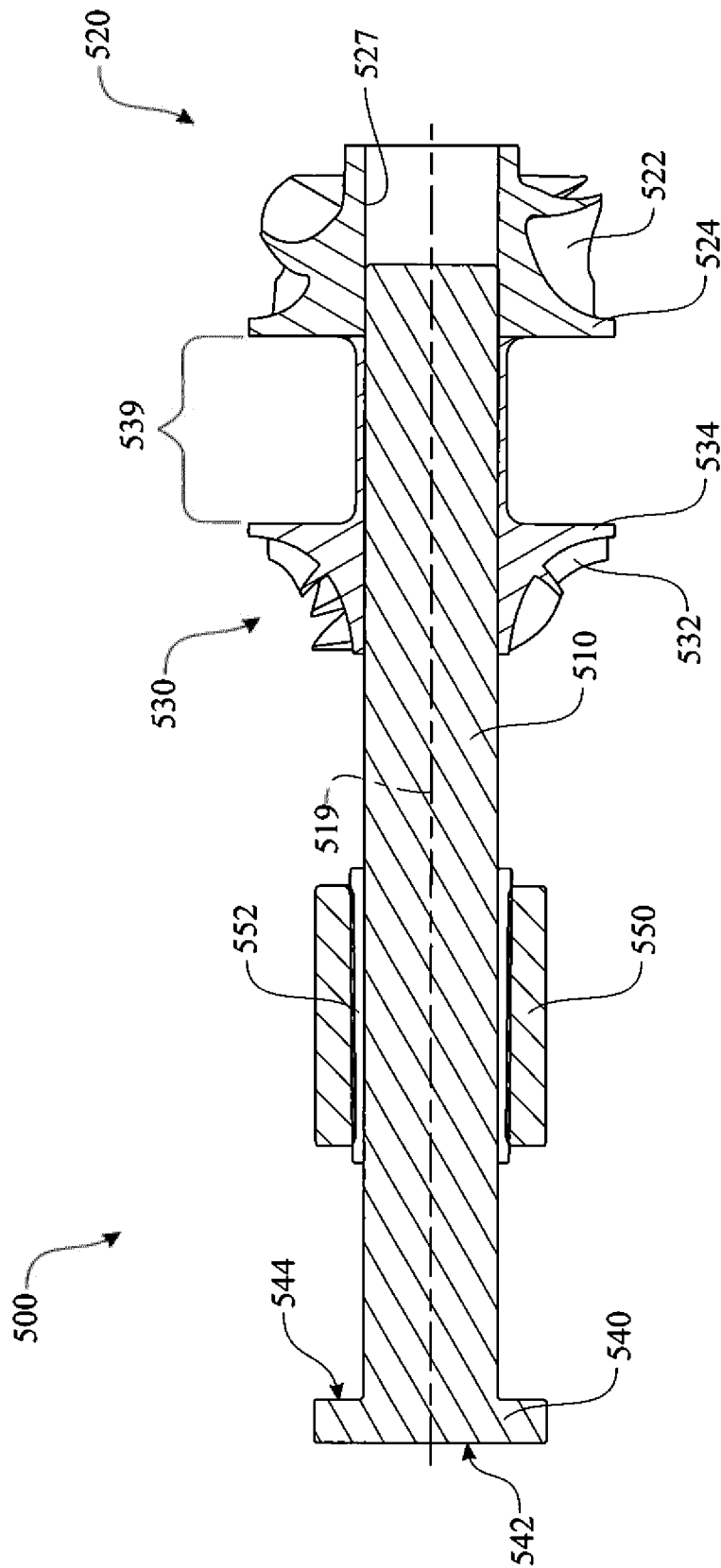


FIG. 16

+

+

17 / 30

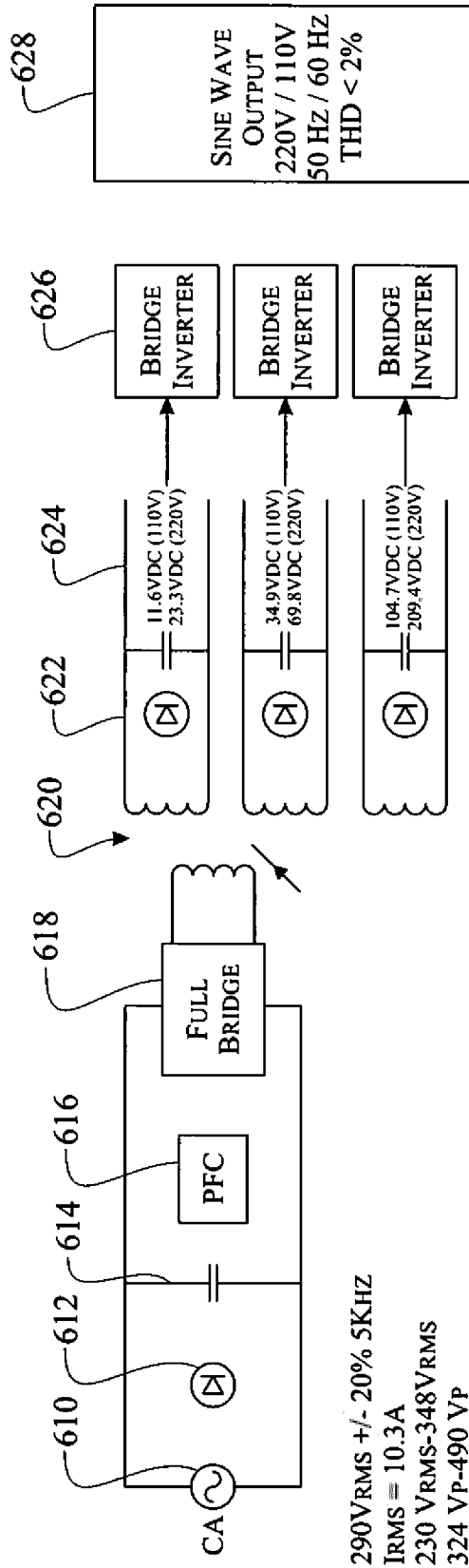


FIG. 17

+

+

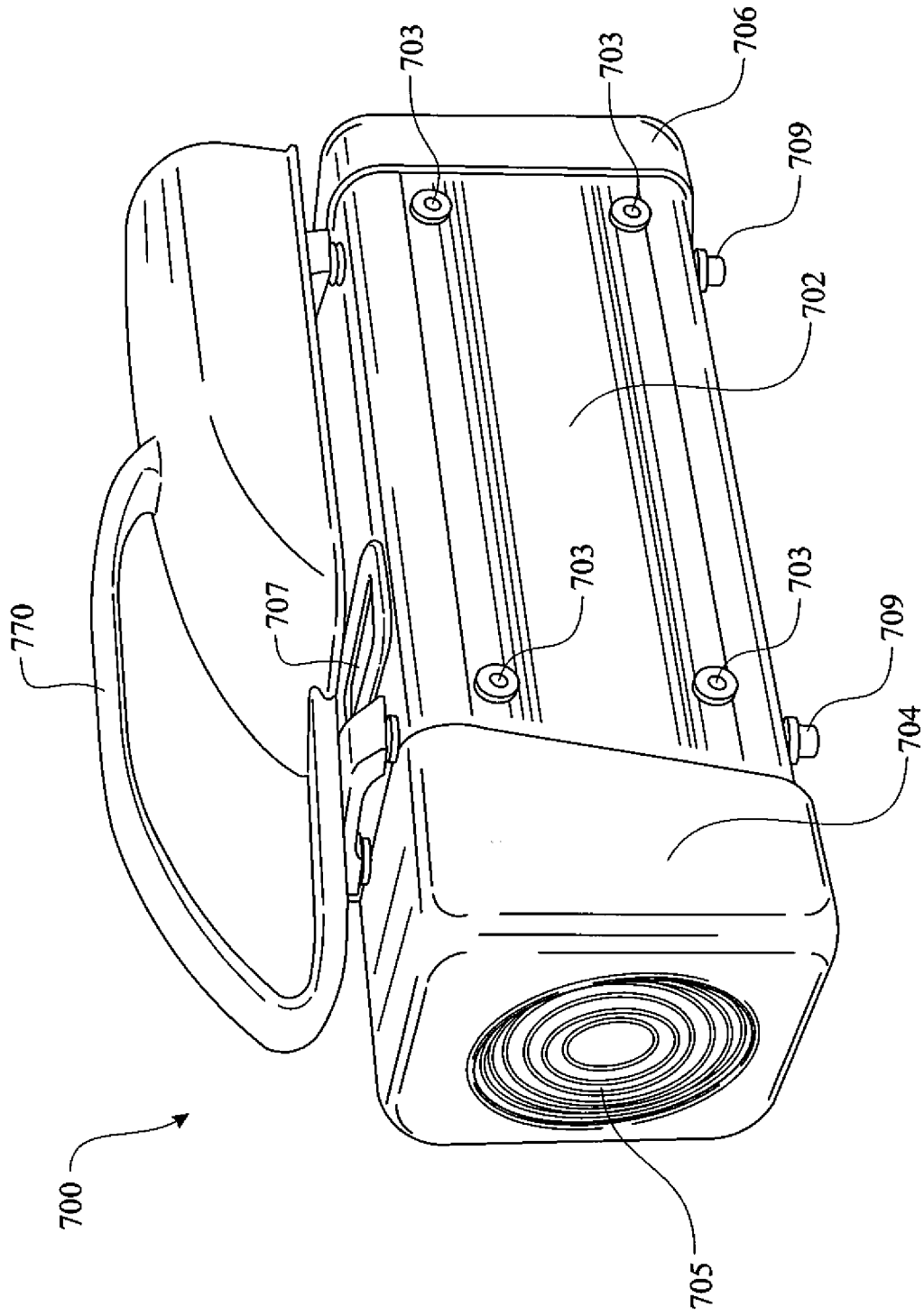


FIG. 18

+

+

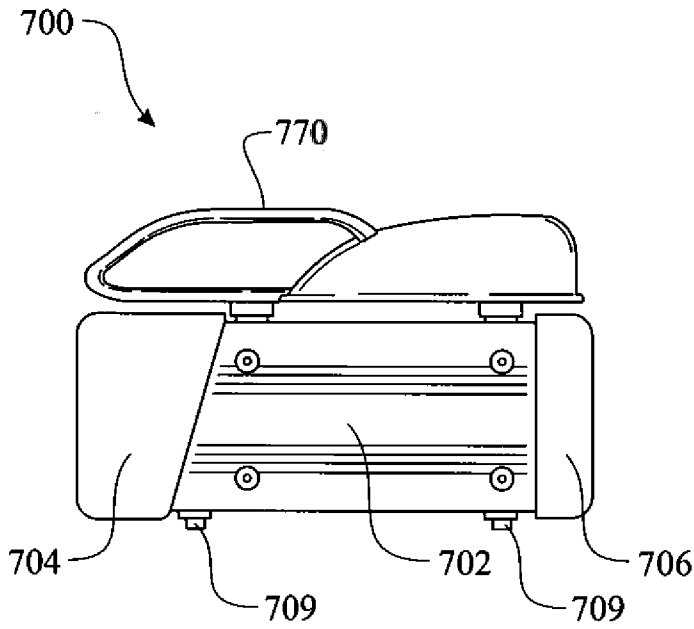


FIG. 19

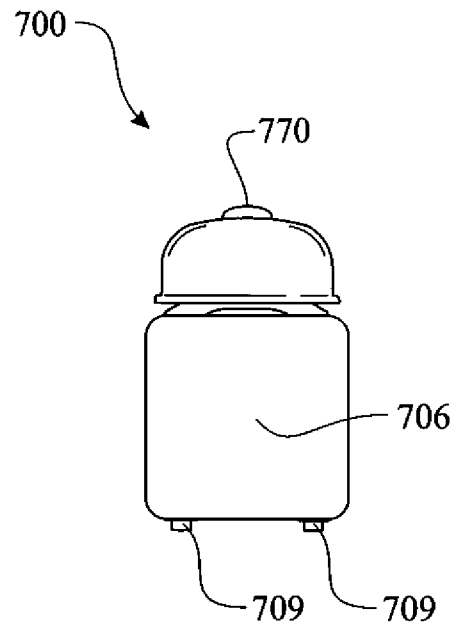


FIG. 20

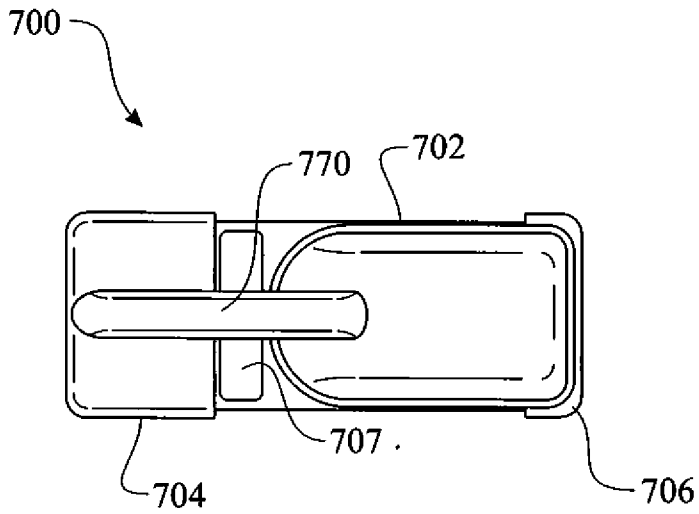


FIG. 21

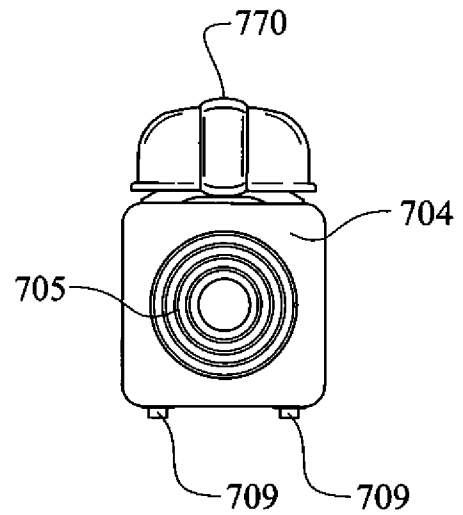


FIG. 22

+

+

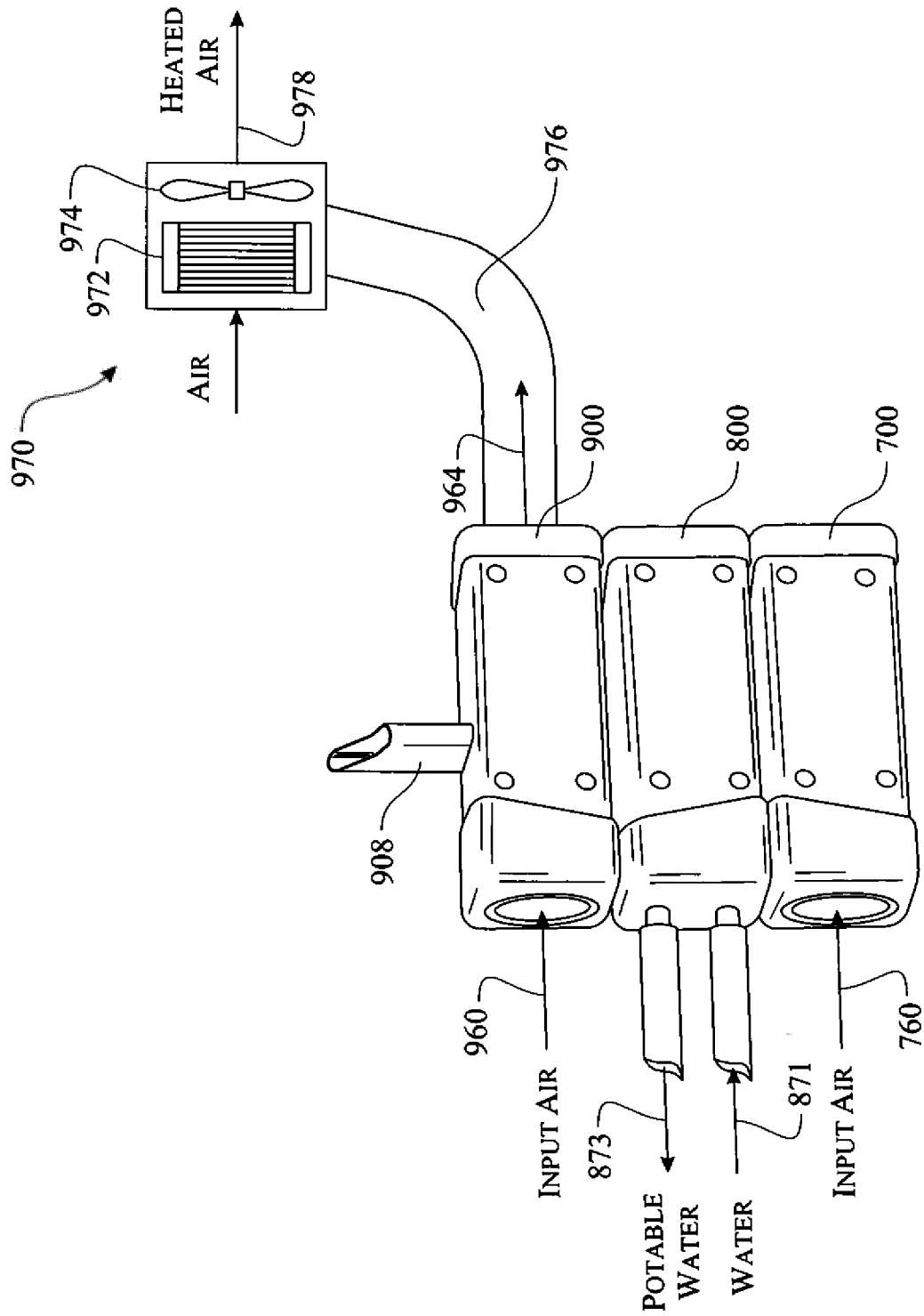


FIG. 23

+

+

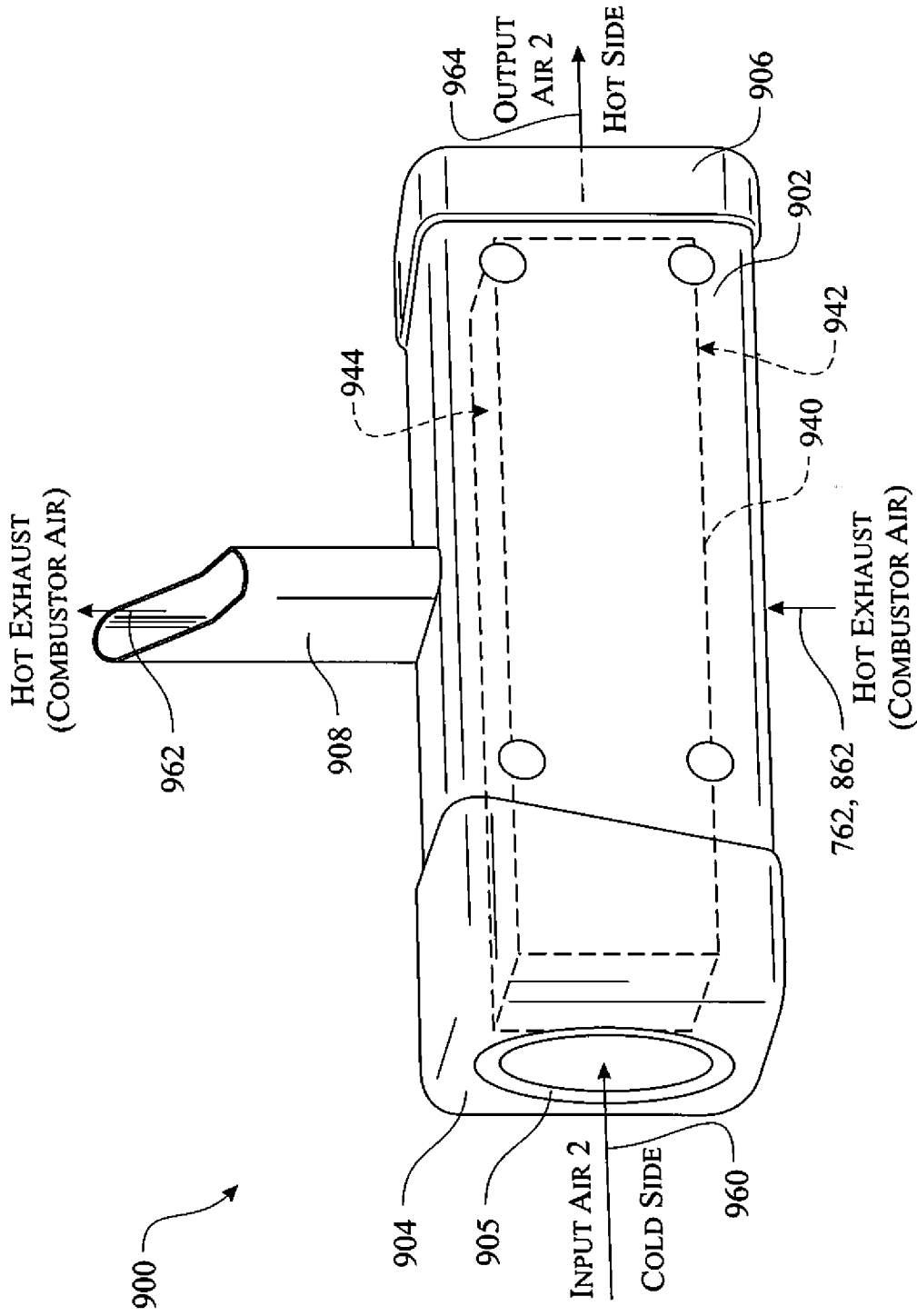


FIG. 24

+

+

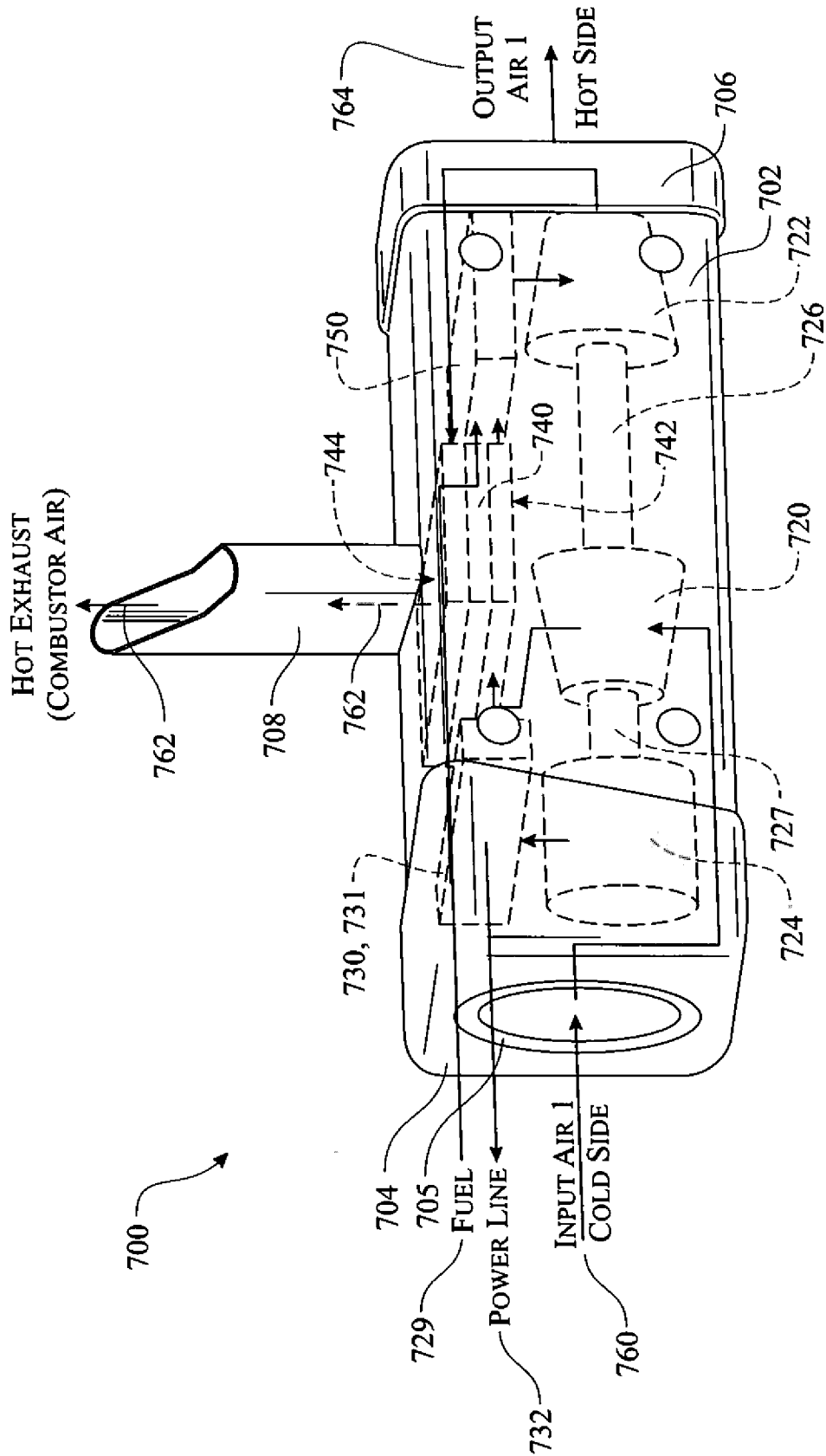


FIG. 25

+

+

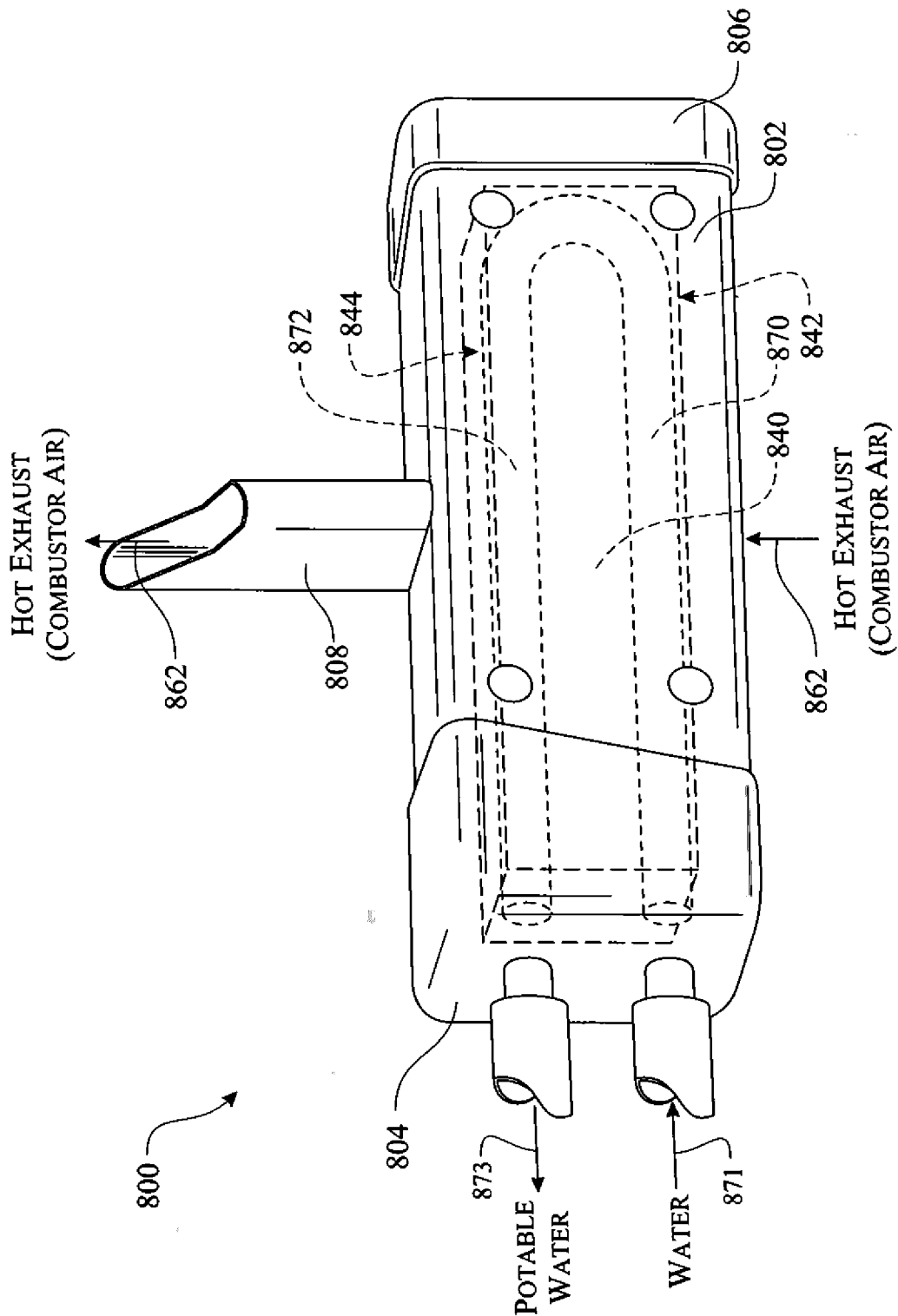


FIG. 26

+

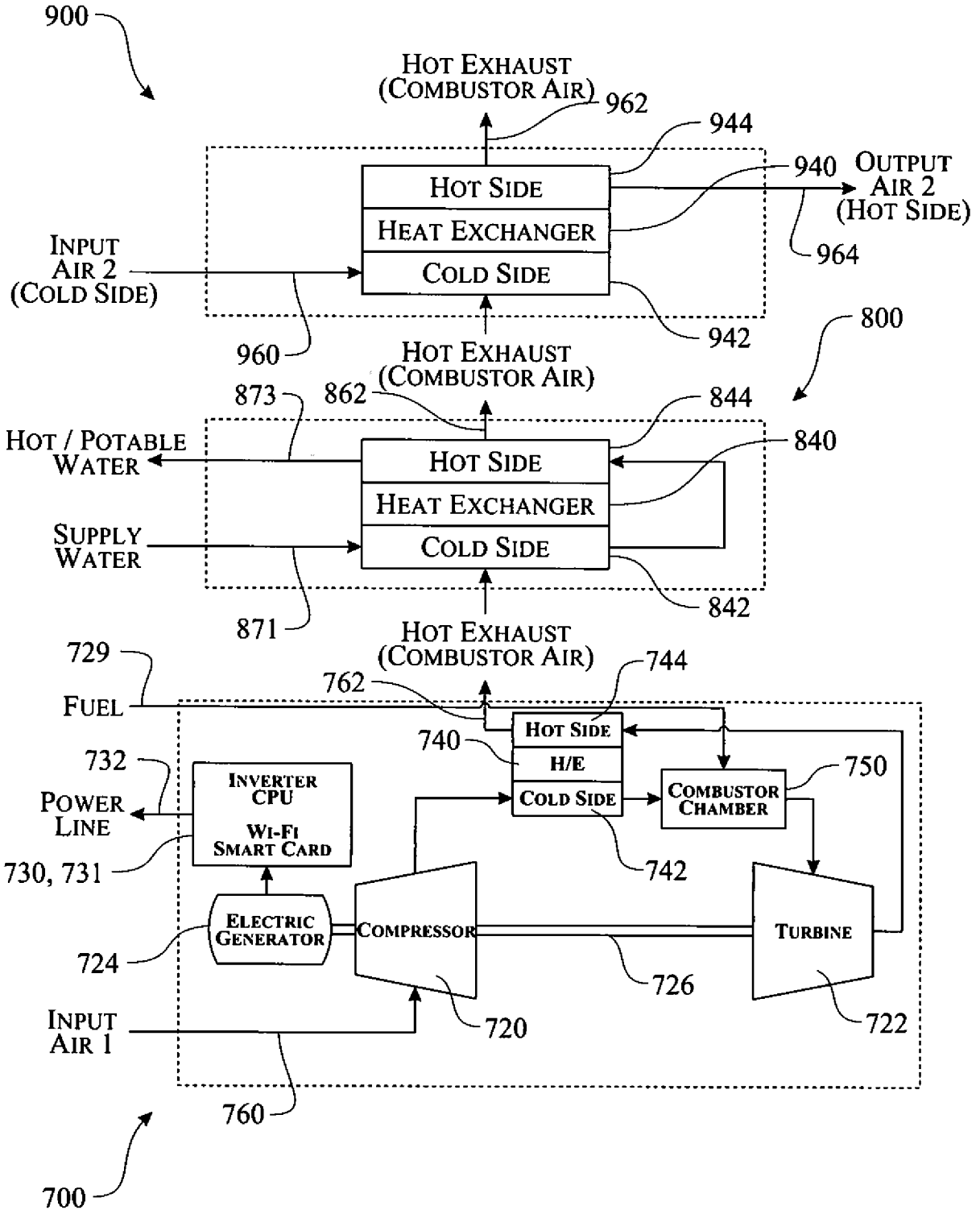


FIG. 27

+

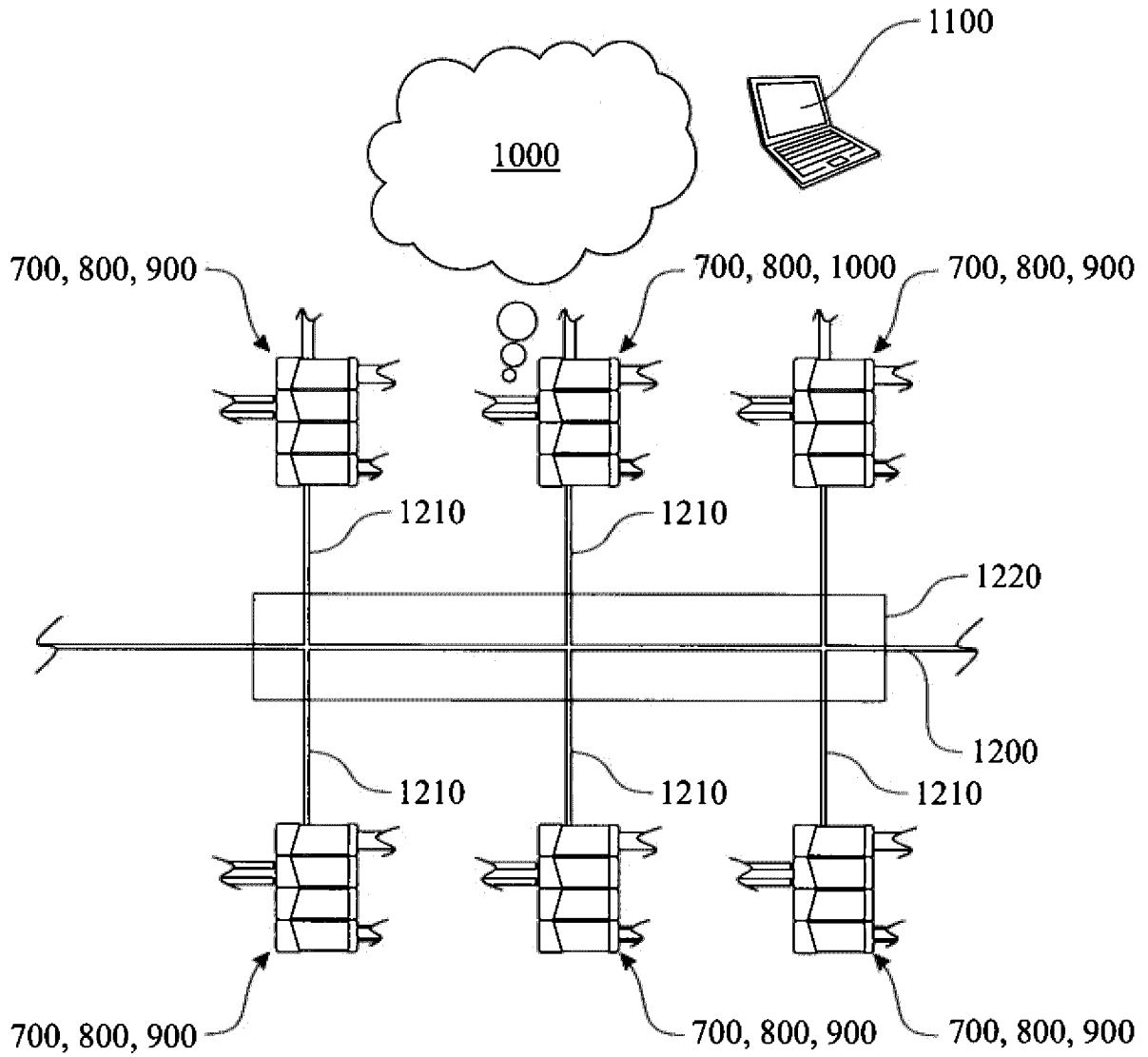


FIG. 28

+

+

26 / 30

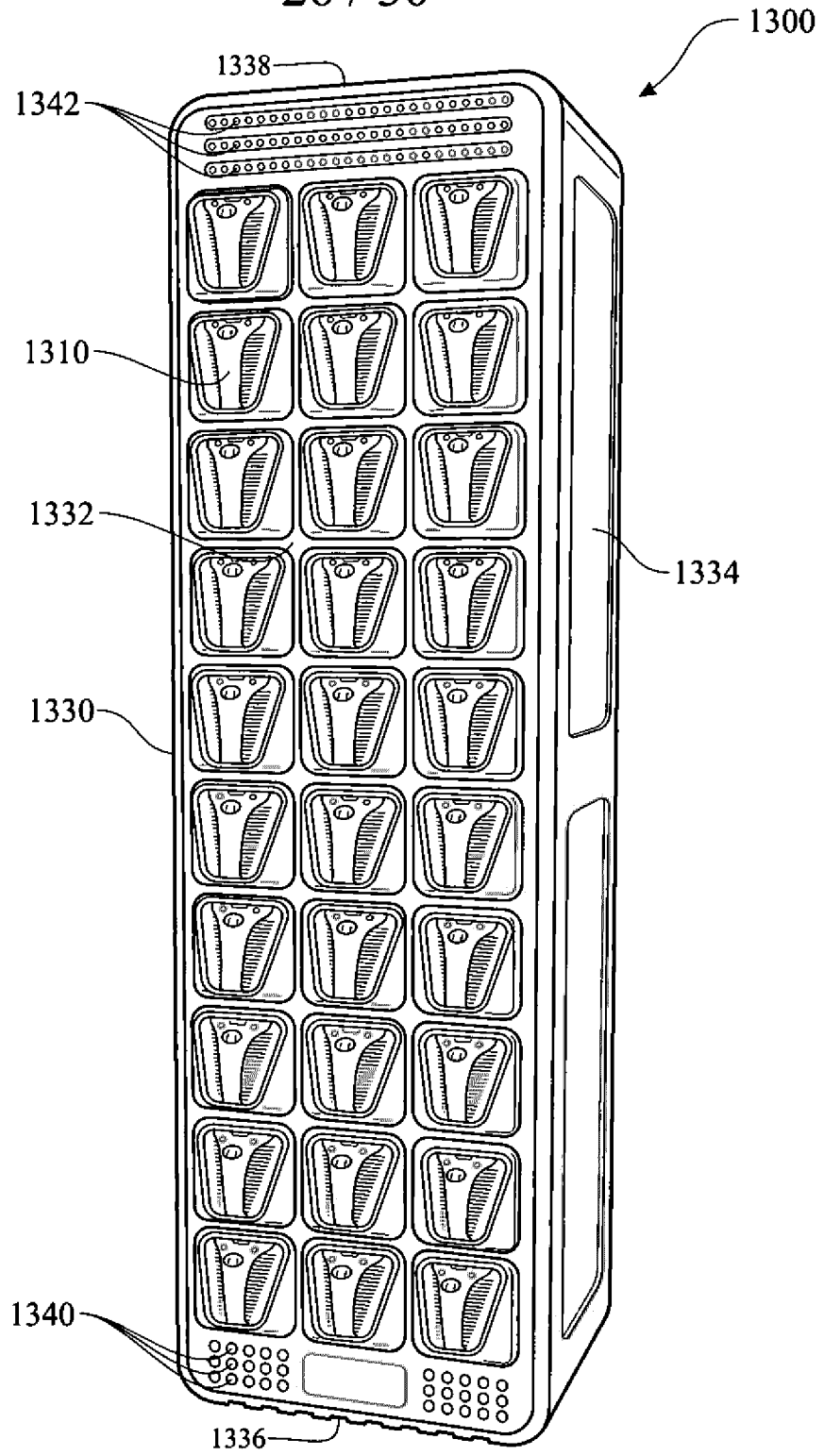


FIG. 29

+

