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(54) **CENTRIFUGAL EXPANDERS AND COMPRESSORS EACH WITH BOTH FLOW FROM PERIPHERY TO CENTER AND FLOW FROM CENTER TO PERIPHERY IN BOTH EXTERNAL HEAT AND INTERNAL COMBUSTION**

ZENTRIFUGALE EXPANDER UND KOMPRESSOREN MIT FLUSS VON DER PERIPHERIE VOM ZENTRUM UND FLUSS VOM ZENTRUM ZUR PERIPHERIE IN EINER EXTERNEN UND INTERNEN VERBRENNUNG

DÉTENDEURS ET COMPRESSEURS CENTRIFUGES COMPORTANT CHACUN À LA FOIS UN ÉCOULEMENT DE LA PÉRIPHÉRIE VERS LE CENTRE ET UN ÉCOULEMENT DU CENTRE VERS LA PÉRIPHÉRIE, AUSSI BIEN À CHALEUR EXTERNE QU'À COMBUSTION INTERNE

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] Broadly, one field is internal combustion engines, especially of the turbine type. A second field is multistage centrifugal compressors. A third field is multistage centrifugal expanders, not currently practiced. A fourth field is external heat engines. A fifth field is guides to change flow direction. A sixth field is the bending of flow paths without significant eddy currents. Sub fields are current art multistage centrifugal pumps, and bearing systems, and jet engine design.

[0002] Within these categories one field is multistage centrifugal compressors comprising a compressor acting in the conventional fashion with flow from the center proceeding to the periphery, followed immediately by a new art centrifugal compressor operated with flow from the periphery to the center. Current art brings the flow back to the center before applying the second stage centrifugal compressor. That was the invention applied to conventional uses of compressors.

[0003] Note that the word expander includes the concept that heat energy and macro velocity in a gas flowing through it is converted into mechanical energy The mechanical energy in the case of a centrifugal expander is received by a rotor pushed by the flow of the gas through the expander. The rotor could be replaced by another mechanical device such as a piston. Most often the temperature of the gas goes down in the interval between entering and leaving the expander. Most often the gas expands within the expander. Usually the gas speed increases in the interval between entering and leaving the expander. A centrifugal expander is defined as a centrifugal pump operated with new art flow directions to act as an expander. In older art the centrifugal pump is mainly thought of as a compressor.

[0004] The use in engines, either internal or external heat, of multistage centrifugal expanders, not commonly known, is another field of the current invention. They can be old art centrifugal compressors run backwards with respect to flow. They can, but need not, comprise a new art centrifugal expander operated with flow going from the periphery to the center and impinging against rotor blades receding from the flow followed immediately by an expander with flow from the center proceeding to the periphery impinging against rotor blades again receding from the flow. The above multi-stages could start flow either at the center or at the periphery and use more than two stages. Four stages on the same axle will be shown in figure 1. The rotors may or may not all be on the same axle. Each stage, using new expanders, has blades held between a couple of discs. The discs need not be flat but can be concave or convex. The distance between the discs of a pair may be smaller or larger at the periphery to account for expansion or shrinkage of the fluid due to pressure drop or due to velocity change or due to temperature change or any combination. Later stages in an expander may have discs further apart than those of earlier stages. Later stages in a compressor may have discs closer together.

[0005] This invention also applies specifically to the above described multistage expanders acting as expanders in an internal combustion engine or hot gas injecting engine. The new art engine consists of a source of pressurized hot gases, for example the exhaust of a jet engine or the exhaust of a burner or simply compressed air heated by solar energy. The pressurized hot gases would be applied either at the center of a centrifugal compressor acting as an expander, or at the periphery of such a compressor acting as an expander. All three possible hot gas sources need a front end compressor, even the jet engine and the burner. In a jet engine air is sucked in and compressed, then a fuel is added and burned producing not only CO_2 and H_2O, but also compressed N_2. Air is 80% N_2. The same products are produced in a burner. In the cases of compressed air heated by solar energy the composition of the hot gas is O_2 plus N_2. The relative amount of N_2 can be increased by burning a lean fuel mixture. In all cases N_2, a diatomic gas, is more than half the input to the expanders. This means that about 8 stages of expansion are necessary using standard steel in the pumps to change the output temperature to half the input temperature giving 50% efficiency. To calculate the necessary number of stages plug in air in the calculator provided by Elliott-turbo.com and the appropriate pressure ratio for air compressed adiabatically to get a temperature ratio of 2:1.

[0006] If input gas is applied at the center, near the axle for the first stage spiral then the blades are pushed by the expanding fluid with a component of the normal to the pushed surface pointing toward the center. The blades appear concave to the pushing fluid while it spirals outward. This would be true of any spiral much like a pinwheel rotating due to the flow. Because of conservation of angular momentum, in the system of blade assembly and pushing fluid, the rotation set up in the spiraling fluid is opposite to the blade rotation.

[0007] If input gas is applied at the periphery the blades are pushed by the fluid. Usually a component of the normal to the pushed surface will point toward the periphery. In this case, the blades appear convex to the pushing fluid, while it spirals inward. The blades rotate so their angular momentum around the axis is in the same direction as the angular momentum of the entering fluid around the same axis. The blades could be straight or even slightly curved the other way, but this would reduce efficiency.

[0008] Some various hookups including the above are shown and discussed with the figures in the specification. The fluid if moving from center to periphery has angular momentum opposite to that of the blades. If the next stage is on another axle rotating in the same direction (clockwise or counter-clockwise) the fluid can flow straight out from the periphery of one stage and into the periphery of the next with the connecting path traveling between the two axles (see figure 5). If the next stage is on another axle rotating in the opposite direction (clockwise or counter-clockwise) the fluid can flow straight out from one stage and into the next with the connecting path traveling on the same side of the two axles (see figure 6). If on the same axle the fluid must turn 180 degrees at the periphery before entering the next stage periphery. The spiral of the blades will then best occur from periphery to center opposite to the spiral of the previous stage blades with the surface of the blade being pushed having a component pointing to the periphery.

[0009] Assuming that the fluid has spiraled inward in a stage, called the prior stage, the fluid must spiral outward in the next stage. Before introducing the fluid into the center of the next stage centrifugal expander, the fluid must go from radial to axial motion leaving this prior stage. This transition will be shown and discussed. The fluid will then be changed from axial back to radial into the next stage (also discussed). The method of transitioning using fluid guides, probably attached to the axle, will be claimed in the claims. The spiral will then occur from center to periphery with the surface of the blade being pushed having a component pointing to the center.

[0010] This invention also applies to external heat engines using multiple stage expanders and multiple stage compressors as described above. In the case of expanders the expansion occurs on both the outward fluid journey and on the inward fluid journey. In the case of compressors the compression occurs on both the outward fluid journey and on the inward fluid journey. Heat exchange heating of the working fluid is applied after compression. Heat exchange cooling of the working fluid is applied after expansion.

[0011] One aspect of the engine of my prior application was that the compressor rotors receive torque from the expander rotors along a common axle. The torque is best carried by a common axle for the rotors, but could be carried by an alternative linkage. If more than one axle is used it would be good and an extension of my prior application to put a balance of expanders and compressors on each axle.

[0012] A second aspect is that a compressor whether centrifugal pump or positive displacement pump can receive mechanical torque from an expander. The moving parts of the compressor and expander and the mechanical connection between them can all be surrounded by the working fluid and by the container surrounding and containing the working fluid. As in my prior application there can also be a dynamo also surrounded by the same pool of working fluid.

[0013] Since the working fluid would be in a very slow moving container, (maybe on a moving vehicle or on a floor), but the axles would rotate very fast, and since the axles should not extend from inside to outside the container, the power could be extracted through one or more dynamos having both magnets and output coils in the same container as the working fluid. The wires from the coils would travel through the working fluid container from being immersed in the fluid to being in the relatively slow moving surroundings of the engine. Thus the coils must be stationary with respect to the container, while the magnets rotate within the container.

Description of Related Art

[0014] One example of prior art is US2429978 which discloses a centripetal-centrifugal pump. It provides a rotating member with an impeller consisting of helical vanes arranged to receive the flow of fluid. A first set of helical vanes are organized to produce a centripetal flow of fluid being pumped and a second set of helical vanes are arranged to produce a centrifugal flow to discharge the fluid.

[0015] For my new multistage centrifugal compressors, the closest related art is the current multistage centrifugal compressors. The flow in all compression stages in current art starts near the axle of the rotors and ends near the periphery of the centrifugal pumps. In my invention I add compression while the flow is moving from the periphery to near the axle.

[0016] For my new multistage expanders, the closest related art might be the current multistage centrifugal compressors, used in reverse flow (although that is not actually practiced). The flow in all expansion stages of current art, not actually practiced, starts near the periphery of the centrifugal pumps and ends near the axle of the rotors. In my invention I add expansion while the flow is moving from near the axle to near the periphery.

[0017] Another related former art is axial expanders and axial compressors. They use many small blades like feathers and thus produce eddy currents near the blades. They are the closest related art. Axial turbines as expanders act as if they have two concentric axles one going clockwise and the other going counter-clockwise. The flow is violently changed in rotation direction by the many blades of each turbine wheel. This is to accommodate the opposite rotation of the next stage. Also the blades pass each other very rapidly. Many eddy currents are produced as a result of both the direction change of gas passing between blade sets and the close passage of the blade sets as well as the use of blades having edges. My new art blades have many less edges For example the edges where my blades connect to the discs that hold them are not active edges because no gas passes perpendicular to these edges. The collecting and releasing edges near the axle and near the periphery are the only active edges and they each can provide a smooth flow parallel to the sides of the blade meeting at the edge. The former axial turbines are used for expansion in power production and used in reverse for compression for example in collecting and compressing air for a jet engine.

[0018] Relating to my new internal combustion engine one close relative would be the Shockwave engines, currently funded for proof of concept by ARPA-E. It is somewhat equivalent to a single stage of one of my engines with flow going from center to periphery of the expander. The expander is analogous to the shockwave chamber but operated with continuous constant speed flow. The problem for the shockwave engine is that they expel the products of combustion at a much higher temperature than I do and thus they lose most of the usable heat energy. A second problem is that the fluid is expelled in a direction which is not as perpendicular to the radial direction, thus losing some torque.

[0019] Relating to the source of heated gas for my engine, one source is solar power heated compressed air. The required heat exchanger is related. Also related is the field of jet engines as a source of heated pressurized gas.

[0020] Relating to my new external heat engine or heat pump using a loop containing a monatomic gas such as argon, the new invention, in one form, replaces the single stage compressors and expanders in my former application with the new multiple stage expanders and compressors.

[0021] There are many external heat engines that expand and contract a working fluid. One of my favorites is the Stirling engine which in its most famous form uses a large piston to oscillate the fluid between being cooled and being heated. The oscillation of temperature is caused by sending the fluid through a regenerator and having a heat exchanger heating source on one end and a heat exchanger cooling source on the other end of the regenerator. The power output piston communicating with the same working fluid as that being oscillated is synchronized out of phase with the oscillator piston. There is friction and pressure and temperature loss at both pistons, but mainly at the output piston. Also in former art Stirling engines the dead volume versus piston displacement must be kept small. The engines of my invention require no piston and no chamber that changes volume, such as a piston chamber. Also a regenerator, which causes power loss by fluid drag and thus pressure loss across the regenerator, and which also causes power loss by temperature difference hysteresis between the regenerator parts and the fluid, is not necessary in my engines, because the full temperature change from hot heat exchanger to cold heat exchanger occurs in the centrifugal pumps. Further, in the case of my new internal combustion engine there are no heat exchangers, unless solar power is used to heat air.

[0022] Other engines use a compressor followed by an expander, but then open to the atmosphere. The closest to my invention use axial compressors that send the fluid along the rotation axis of an impeller. A jet engine, for example, is an internal combustion engine that can use a compressor up front. The impeller moves with respect to its housing. This produces energy loss even when the engine is only idling. It may also cause problems when the blades move faster than the speed of sound with respect to the casing in which they reside. If multiple compressor blade groups are used then eddy currents and turbulence will develop wasting energy. On the other hand, in most of my designs, I put a disc on either side of the rotor blades, so that the blades do not sweep along their immediate surroundings.

[0023] My earlier invention, now patented, (and also all of my new engines) have almost zero losses due to motion of parts with respect to each other. The rotors are attached to the container in my earlier US patented invention. However, in the preferred embodiment of that patent, it rotates the whole container of the working fluid and thus is best used in solar power, where the hot heat exchanger can be fed on the fly by solar radiation moving at the speed of light from the sun. My new inventions, while having rotors moving with respect to their casing, can have the rotor blades protected between substantially disc-like plates, so that the blades do not move with respect to their immediate surroundings, namely the discs also called plates. The discs themselves can be away from their surroundings, except on or near their peripheries. They can also diverge as their perimeters are approached to allow the fluid gradually more cross-section to flow through. Each disc being symmetric around its axle or extended axle, causes little drag on the surrounding working fluid.

[0024] My new invention has little energy loss when idling, since the impellers are contained within a pair of rotating discs, so that no part sweeps past another part at other than a zero angle with respect to each other. In other words the fluid is not scraped off a surface near the impellors, as would be the case with current designs, used in, for example, a jet engine pre-compressor. Also my engine has no moving seals contacting the working fluid, thus requiring no lubrication other than bearings for axles carrying rotors.

[0025] The most closely related art would be centrifugal compressors and turbomachinery. To maximize the ratio in pressure between an input near the center and an output near the periphery of a compression fan, the spiral of the blades as they go from the center to the outside should be retrograde (counter to the rotation direction). To get a larger pressure ratio between an input near the periphery and an output near the center of a compression fan, the spiral of the blades as they go from the center to the outside should be (the same as the rotation direction) so as to scoop in the fluid.

[0026] A similar statement applies to blades of inward and outward bound expanders, except that the rotations of the blades are reversed. Thus blade normals tend to aid flow between center and periphery in a compressor and tend to oppose flow in an expander.

[0027] Typical multistage compressors, such as those shown on the website of Elliot-turbo, compress in a stage as the fluid travels outward to the periphery. Before the next and similar stage the fluid is guided in stationary ducts from the periphery to near the axle again. My invention uses that travel from periphery to center to continue the compression by using a rotor in that path as described above. Thus for every stage in the Elliot-turbo design I have two stages, one going outward and one returning.

[0028] I do not know of multistage expanders using rotors. Also I do not know of multistage expanders or compressors combining two stages into one round trip for the working fluid from periphery to center and back to periphery or combining two stages from center to periphery and back to center.

[0029] The larger the pressure ratio, the larger the temperature ratio can be and thus the larger the theoretical efficiency of the engine. The current limit of the compression ratio on single stage centrifugal compressors is about ten to one (10 to 1), when pushing air. External heat will be added after the compression. For a monatomic gas the temperature ratio is 2 to 1, given a pressure ratio of between 6 and 7. The 2 to 1 ratio in absolute temperature means a theoretical efficiency of 50% converting heat to mechanical energy. That is the theoretical efficiency of a Carnot engine operating between those temperatures. My invention for a heat pump or external heat engine can achieve a much higher temperature ratio, and therefore efficiency, when argon or a mixture of krypton and helium is used. These three gases are monatomic.

[0030] When considering the efficiency of my internal combustion engines the necessary pressure ratio for diatomic gases such as nitrogen which is 80 % of the air used is about 12:1 to get a temperature ratio of 2:1. The necessary pressure ratio doubles again if most of the burning byproducts are CO_2 and H_2O. However, no one uses pure oxygen for internal combustion, so a mix heavily weighted toward N_2 is output and if the engine runs lean then even more weight can be given to the N_2 and O_2 components thus lowering the necessary pressure ratio.

[0031] According to formulas for adiabatic compression, for a given pressure ratio the temperature ratio for a monatomic gas is greater than it is for a gas consisting of multiple atoms per molecule. The multiple atoms in a molecule supply more degrees of freedom and thus more capacity to store the heat caused by the compression. This higher temperature ratio for monatomic gases versus diatomic gases and the higher temperature ratio for diatomic gases versus gases having more atoms per molecule is important for engine efficiency as mentioned above.

[0032] Ideally the blades of the centrifugal pump rotors meet the fluid or in the opposite direction expel the fluid so that the fluid is traveling in a direction parallel to the blade surface just before contact and just after leaving each blade. Each blade may be replaced by several blades at varying distances from the axis. Ideally, for maximum efficiency the pressure difference in each rotor is maximized producing the largest temperature ratio possible. The extreme pressure ratio achievable on centrifugal compressors for air is about 10:1 in current art. At ratios above ten for air the compressor may wear out fast and may be dangerous. There is a lesser problem with a heavier gas such as Argon or Krypton. A ratio of 7:1 would be adequate for very good efficiency, reduced risk, and reduced energy loss within the engine. With Argon, that pressure ratio causes more than a 2:1 ratio in temperature, adequate to get nearly a 50% efficiency. Krypton is twice as heavy as argon and thus will produce a much higher pressure ratio and higher efficiency, but it is more scarce and costs more. Efficiency is more important in a solar collector system. The ratio of the number of mirrors necessary is equal to the ratio of efficiencies. In a solar collector system, number of mirrors is inversely proportional to efficiency to get the same energy output. Argon is about 1% of the atmosphere. Thus when oxygen 20% of atmosphere is extracted the amount of argon by-product is about 5% of the amount of oxygen.

[0033] In the case of external heat engines, in order to get power from the rotors transferred to outside the working fluid container, it is best to use a dynamo. The wire carrying the current and voltage can penetrate the container from inside to out without friction loss or fluid loss. The rotation of the rotor can be used to rotate magnets attached to a cylinder which is attached to a disc of the rotor. The magnets would be pointing inward toward the axis while the stationary wires will be attached to a stationary central stem which would be on an imaginary extension of the rotor axis. Both the magnets and the wires should be encased in material to make them aerodynamic during rotation. The magnets will be in a fluid substantially rotating with the magnets. The coils will be in a swirl of fluid set in motion by the magnets. Thus drag at the magnets is minimal. That drag is induced by the slowing of the swirl caused by the stationary coils, which drag on the swirl, but near the rotation axis where the velocities and effects are less. Also, the pressure is less near the center. The pressure near the center can be further reduced by allowing some leakage into the area from the pump disc and simultaneously preventing the higher pressure from the periphery from getting in. Instead of encasing the magnets the material of the magnets can be shaped like a tire, which would be aerodynamic. So the fields of fluid dynamics and of dynamos would apply.

[0034] The rotation of the rotors can be started either by using the dynamo as an electric motor or by attaching electric motors on the pumps not having dynamos attached. The wires would of course pierce the fluid container and one set of coils should be stationary. A commutator could be used, since the electric motor will not operate for long periods and the commutator could be disengaged at high speeds. Better than a commutator for a motor would be an optical sensor that would change the polarity of the voltage applied to the coils of the dynamo depending on the position of the magnets. The voltage applied would be controlled by electrical amplifiers, between the sensor and the dynamo coils, in obvious ways. So the fields of electronics and dynamos would apply.

[0035] Electromagnetic bearings such as are used in centrifuges can be used for the high rotation rates associated with the rotors, once they reach operational rates.

The technology used for high speed trains would also apply, since the circumference of the rotors, actually of the discs holding the rotors, is moving very fast.

[0036] One object of the current invention was to produce an engine/heat pump which, when operating at a steady speed, has no changes in temperature at any particular point. Thus heat loss due to changing operating temperatures at a particular position are negligible, since the temperature of the working fluid is always the same as the temperature of its nearest container wall. This is accomplished by using the centrifugal pumps thus allowing smooth unidirectional flow both in the pumps and in the fluid connections between the pumps. Where positive displacement pumps are used in former art there are wild temperature variations at points in the pumps. Where regenerators are used there are wild temperature variations at points in the regenerators.

[0037] Heat loss due to conduction along the parts with spatial temperature differences, mainly in the compressor and expander where temperature as a function of position changes rapidly, can be minimized in several obvious ways, including putting an insulating layer on the surface contacting the working fluid. To protect the magnets, if used, from high temperature, it would be wise to remove the insulating layer near the axle, so that heat can escape from the dynamo to the rotor or cooler part of either the expander or compressor, depending on whether the dynamo is located near a compressor or an expander. A compressor would be cooler.

[0038] Another object of the current invention was to produce an engine where there is essentially no loss of pressure around pistons or blades. Prior engines would produce localized circulations and turbulence especially where the blades are close to the blade casing. There is rapid relative motion between closely spaced components in most if not all prior art. In my invention the amount of casing which is near moving parts is minimized by locating the blades between discs. Also moving surfaces at an angle to the container, where the intersection of the surfaces is moving, are minimized or eliminated by using discs to hold, encase, and rotate with the rotor blades.

[0039] Another object of the invention applied to external heat engines was to produce an engine that would have no loss of working fluid to the outside or around pistons, since substantially the working fluid is in a container that does not change shape or volume, except for stress or strain. There are no moving elements that pierce the skin of the container. Argon and krypton gas would not permeate or escape from its enclosure if steel is used. Only the electric wires pierce the skin of the working fluid container.

[0040] Another object of the current invention was to produce an engine which produces very little metal fatigue, since the rotating parts maintain a nearly constant rotational speed thus keeping stress almost constant. Metal fatigue in former art is caused by metal bending back and forth under varying stress.

[0041] Another object of the current invention is to produce an engine that needs no lubrication, except at the axles. There is no other friction wear in the engine.

[0042] Another object of the current invention is to produce an engine that needs no seals. The seals could produce a problem in other engines at high temperature.

[0043] Another object of the current invention was to produce a very low loss heat pump that allows the temperature ratio to be varied, by varying the rotation speed.

[0044] Another object of the current invention was to produce a heat pump that can be made mostly from aluminum and use argon as the working fluid.

[0045] Another object of the current invention is to use a rotor to eject fluid at a high pressure near the periphery, the rotor consisting of tubes having increasing cross-section as we move outward from the rotation axis. The tubes may be comprised of two consecutive blades and that portion of two discs extending between the blades. The discs, which sandwich the blades between them thus supporting the edges of the blades, may flare outward away from each other as we travel away from the rotation axis, thus looking something like parabolic mirrors. They should approach the fluid container at or near their periphery and no sudden change should be made in the flow cross-section as the fluid enters the conduit between pumps. It may be useful to have a knife edge on the periphery of the discs, so the discs can remain strong and yet approach the conduit entrance smoothly with the surface closest to the blades.

[0046] The above objects apply both to the old patent 8,087,247 and to the new application and to my older application. The below objects are newer and apply to the new application and to my older application.

[0047] Another object of the current invention is to produce an engine having the smooth uniform flow properties of the current invention and also allowing the heat exchangers of an external heat engine to be any size and located anywhere and stationary, limited only by the pressure losses due to fluid drag within them. For example, a Stirling engine, for efficiency, should limit the size of its heat exchangers to less than the swept volume in its pistons. My previous patented inventions in their specification, other than the claims, were limited as to location of the cold heat exchangers and the examples showed the heat exchangers in motion. For another example, the hot heat exchangers, if tubes, can be placed in a stack, so that some parts are in the flames and others are heated by the exhaust products of combustion.

[0048] Another object of the current invention is to produce an engine where the only moving parts are the rotors, the dynamos attached to rotor discs, and the rotor axles. If one of these parts fails, the broken pieces may be contained by the fluid container, thus preventing damage to surroundings.

[0049] Another object of the invention was to produce an engine with negligible friction loss, since there are almost no solid parts moving relative to each other due to the engine cycle. Of course, as with most engines, the rotor shaft is rotating with respect to parts of the device supporting the shaft, such as bearings whether ball or magnetic. Also, the perimeters of the discs holding the rotor blades will move in a circle relative to the container of the working fluid. We have a moving circle at the periphery of the disc opposing a fixed circle, the configuration looking the same at all times and thus minimizing fluid induced drag.

[0050] Another object of this invention is to produce an external heat engine where a compressor is driven by an expander, the torque being transferred by a mechanical connection, such as an axle, fully contained within the working fluid container. Any mechanical connection, not necessarily axle could be used. Also any type of compressor or expander, such as those using rotary gears, could be used.

[0051] Another object of this invention is to drive a dynamo using torque from an expander to the dynamo and using a wire from the dynamo, piercing the fluid container to carry power from inside the engine to outside the engine.

[0052] Another object of this invention is to make the wire coils and also the magnets of the dynamo aerodynamic, either having circular symmetry around the axle extended or being encased in a material having circular symmetry around the axle extended. This would reduce drag and eddy currents in the working fluid between the coils and the magnets.

[0053] The below objects apply to the current application but not the other mentioned application or the mentioned patents.

[0054] Another object of this invention is to produce a more efficient multiple stage centrifugal compressor that compresses fluid both while the fluid is traveling from near the axle of a rotor toward the periphery of the rotor and while the fluid is traveling from the periphery of a rotor toward the axle of the rotor.

[0055] Another object of this invention is to produce a more efficient multiple stage centrifugal expander that receives mechanical energy from a fluid both while the fluid is traveling from near the axle of a rotor toward the periphery of the rotor and while the fluid is traveling from the periphery of a rotor toward the axle of the rotor.

[0056] Another object of this invention is to provide an efficient means being fluid flow guides to change the flow from radial inward motion to axial motion and an efficient means being fluid flow guides to change flow from axial motion to radial outward motion. Similarly at the periphery there are smooth transitions to transfer from the outward flow to the inward flow.

[0057] Another object of this invention is to show a new type of internal combustion engine or more generally a hot compressed gas engine comprising a part of the whole engine which part converts hot gas entering it under pressure to energy of motion and expels cooler gas. This part would very likely consist of an expander using centrifugal expanders.

BRIEF SUMMARY OF THE INVENTION

[0058] This invention is a set of related inventions, comprising a group of flow guides to convert radial flow to axial flow and a group to convert axial flow to radial flow, both conversions being done with less eddy currents than if the flow guide are not added to break the flow into a number of substantially parallel flows. Of course the two groups of flow guides can be combined into one group of flow guides that receive flow traveling toward the axle of a centrifugal pump and turns the flow so it is traveling away from the axle in a separate centrifugal pump.

[0059] The invention also includes the use of combinations of centrifugal pumps used to form a multistage compressor with at least one pump processing a flow of gas traveling from the vicinity of the axle toward the periphery of the pump and with at least one other pump processing the same flow of gas traveling from the periphery of this other pump toward the axle of this other pump. The word processing substantially means converting between mechanical energy and heat energy.

[0060] The invention also includes the use of combinations of centrifugal pumps used to form a multistage expander with at least one pump processing a flow of gas traveling from the vicinity of the axle toward the periphery of the pump and with at least one other pump processing the same flow of gas traveling from the periphery of this other pump toward the axle of this other pump.

[0061] The invention also includes either the use of the above centrifugal multistage expander or the use of the above centrifugal multistage compressor or the use of both in an external heat engine or in a heat pump.

[0062] Another object of this invention is to show a new type of internal combustion engine or more generally a hot compressed gas engine comprising a part of the whole engine which part converts hot gas entering it under pressure to energy of motion and expels cooler gas. This part would very likely consist of an expander using centrifugal expanders.

BRIEF SUMMARY OF THE INVENTION

[0063] According to the present invention there is provided a multistage expander or compressor according to claim 1.

[0064] This invention is a set of related inventions, comprising a group of flow guides to convert radial flow to axial flow and a group to convert axial flow to radial flow, both conversions being done with less eddy currents than if the flow guide are not added to break the flow into a number of substantially parallel flows. Of course the two groups of flow guides can be combined into one group of flow guides that receive flow traveling toward the axle of a centrifugal stage and turns the flow so it is traveling away from the axle in a separate centrifugal stage.

[0065] The invention includes the use of combinations of centrifugal stages used to form a multistage compressor with at least one stage processing a flow of gas traveling from the vicinity of the axle toward the periphery of the stage and with at least one other stage processing the same flow of gas traveling from the periphery of this other stage toward the axle of this other stage. The word processing substantially means converting between mechanical energy and heat energy.

[0066] The invention also includes the use of combinations of centrifugal stages used to form a multistage expander with at least one stage processing a flow of gas traveling from the vicinity of the axle toward the periphery of the stage and with at least one other stage processing the same flow of gas traveling from the periphery of this other stage toward the axle of this other stage.

[0067] The invention also includes either the use of the above centrifugal multistage expander or the use of the above centrifugal multistage compressor or the use of both in an external heat engine or in a heat pump. gases is operated conventionally, the gas is input to the pump at its conventional input near the center of rotation of the rotor and the gas is output at the conventional output, which is located near the periphery of the pump. The flow output from the expander goes to a heat exchanger used to remove heat. This heat exchanger may or may not be the original heat exchanger to remove heat mentioned above at the start of this paragraph. The temperature ratio from input to output of the at least one compressor is bigger than the temperature ratio (in the heat exchanger) from the output of a compressor to the input of the next expander. This is accomplished by using a monatomic gas combined with a high pressure ratio in a compressor. The temperature ratio in the expanders may be comparable to but not necessarily the same as the inverse of the ratio in the compressors. Of course any external heat engine including the one described above can be operated as a heat pump. The fact that the ratio in the expander and compressor are almost equal can be seen better in the engine described in patent number 8,087,247. The effects in the rotating drum of that invention are more obviously equal.

[0068] In the best design of my former application, the engine of my prior application consists of an axle with a rotor on each end and another axle with a rotor on each end. This configuration represents two engines in series. Each engine has a single axle with a pump at each end. Each of the four rotors is part of a respective centrifugal pump. The rotor on one end of an axle is part of an expander and the rotor on the other end is part of a compressor. The center inlet of one pump on one axle is connected to the center inlet of the second pump on the same axle by a cool fluid conduit, which also contains a heat exchanger to remove heat from the flow while the fluid travels from one centrifugal pump to the other. The other two pumps, which are on the other axle are hooked up for cooling between them in the same way.

[0069] Further, in my former application, the housing which holds the working fluid surrounds the four rotors and the axles, among other parts. It is shaped so as to complete the centrifugal pumps. It is also shaped to contain, except for part of the cooling fluid path, the heat exchangers on the cool fluid conduits traveling along the axles. The cooling fluid enters and travels separately with respect to the working fluid along those conduits in a reverse direction to the flow of working fluid in those conduits. The rotor blades for each rotor are sandwiched between a respective pair of discs to which they are attached.

[0070] Do not take the word discs too literally. They will probably be thinner, knife edged, at the perimeter and thicker near the center of rotation. They may also diverge from each other as their perimeters are approached. This divergence helps to slow the acceleration of the working fluid and increase the pressure change. The fluid pressure change rather than flow rate is emphasized at the output from the compressor. The discs also prevent the blades from sweeping working fluid from their surrounding surfaces. Each blade may be replaced by multiple blades at varying distances from the rotation axis. A set of blades may be rotatable to a small extent relative to the discs holding them in place. Rotated blades could allow the engine to compensate for the effects of differing speeds by adjusting blade angle so that the fluid always meets each blade substantially parallel to the blade surface.

[0071] Further describing my former application, attached to at least one outer disc for a compressor or for an expander is an array of magnets or the holder of the array. This is part of a dynamo to extract electric power from the engine. The output voltage coils of the dynamos are attached to wires which penetrate the housing which holds the working fluid. Thus the coils are stationary with respect to the housing of the pumps. The discs holding the blades and also the blades are thermally insulated on their surfaces to minimize heat loss, except near the axle where it is desired to have heat flow through a disc from inner to outer surface to cool the dynamo volume containing the magnets.

[0072] Further describing my former application, the fluid output from the periphery of each of the two centrifugal pumps being used as compressors is connected by a hot fluid conduit to the input at the periphery of a respective one of the two centrifugal pumps being used as expanders. The two hot fluid conduits each has a means to add heat to the working fluid as it passes through them. This means may be a second fluid conduit which enters the hot fluid conduit, or the heating may be applied directly to the hot fluid conduits, each of which may comprise multiple tubes. Of course, each cool fluid conduit could also comprise multiple tubes.

[0073] For my former application, the hook-ups for the two expanders and two compressors have just now been described above. The axles holding the rotors would probably be mutually parallel. The hot fluid conduits need not be straight. Thus the axles may be close together without limiting the length of the conduits, if each hot fluid conduit travels from one axle to the other. If the conduits are straight, then the rotor configuration looks a lot like the four wheels of a car. If the rotations are in the same direction, then one hot fluid conduit would be above on one side of the car and the other conduit would be below on the other side. If the axles rotate in the opposite directions, then the fluid in one hot fluid conduit on one side of the car would travel from above to below and the fluid in the other hot fluid conduit on the other side of the car would travel from above to below also. In other words for the hot heat exchanger entrance and exit, there is always a switch from above to below or vice-versa when going from one axle to the other if the one axle rotation is in the opposite direction from the other.

[0074] A second version of the engine in the former application could contain only one axle and two pumps. It would have one cold heat exchanger conducting working fluid along the axle between the central openings of the two centrifugal pumps. The hot heat exchanger would conduct working fluid from the peripheral output of the compressor to the peripheral input of the expander.

[0075] Neglecting losses, the power output of the engine is the net difference between the power input to the compressor and the power output from the expander. Since the fluid is further heated and thus expanded after compression, it is traveling at a higher volume flow rate into the expander than it was flowing leaving the compressor. This allows it to do more work in the expander than was used in the compressor.

[0076] Of course the pressure difference from input to output of the compressors must exceed the pressure difference from input to output of the expanders for the engine to balance, since we are dealing with a closed loop, and since some pressure losses will occur in the heat exchangers. Therefore, it is best to have a more pronounced spiral in the compressors than in the expanders.

Heat Pump Aspect

[0077] It may be easier to understand how any device using centrifugal compressors works as a heat pump, since there is no extremely variable load. Suppose we have a drum or wheel of a compressible fluid rotating. If we now cause fluid to migrate from the center to the periphery of the wheel, as would happen in the compressor fan, this fluid will compress thus raising its temperature. If the fluid is now sent back toward the center of rotation, as would happen in the expander fan, the fluid will expand thus cooling. Thus we have a difference between the temperature at the periphery and the temperature near the center of rotation of a rotor. This temperature difference can be used, assuming heat exchange, as in a heat pump and mechanical energy must be added to continue the rotation. The rotation energy must be added, because the fluid in a heat pump is traveling with higher volume flow at the same distance from the rotation axis in the compressor than in the expander, thus making the energy used in the compressor greater than the energy recovered in the expander. As an aside, the opposite was true of the engine. In a heat pump, heat is added to the working fluid (taking heat out of the surroundings) after expansion but before compression, because that is how a heat pump works at the cool end. Similarly heat is removed from the working fluid to the surroundings at the warm periphery, just before expansion. The addition and removal of heat affects the volume flow not the mass flow. Volume flow affects fluid speed and thus its momentum change and thus pressure on the blades. Of course the cross-section through which the fluid flows could be larger thus creating more force on the blades with the same pressure.

Pressure and Rotation G Force Considerations

[0078] The engine or heat pump can be operated with the working fluid held at many atmospheres, usually about 100 atmospheres. It can also be operated at very large rotational G forces. If the compressor is operated near a 7:1 pressure ratio, a large part of that ratio is caused by G forces. Another large part of the pressure ratio is due to the spiral blades pushing the fluid with a radial component. The pushing is caused by inertial effects as the blade tries to increase or decrease the angular momentum of the fluid in the compressor or expander respectively. The rest of this application will refer to the new invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0079]

Figure 1 shows four centrifugal pumps, pairs of which are connected in the sense of flow near the axle. The flow guides near the axle convert radial motion in one pump to axial motion and then convert the axial motion to radial motion in the second pump.

Figure 2 shows a blowup of the flow guides and associated pump parts for one pair of pumps. It also shows the ball bearings between pump pairs.

Figures 3 and 4 show cross-sections A-A, B-B, C-C, and D-D. These display the blades of the pump rotors and the direction of the rotors rotations and the flow of the gas for a multistage expander.

Figure 5 shows how expanders with radial outward flow are linked at their peripheries with expanders with radial inward flow in a multistage expander.

Figure 6 also shows how expanders with radial outward flow are linked at their peripheries with expanders with radial inward flow in a multistage expander, but with axles rotating in opposite directions.

Figure 7 shows a more rounded set of flow guides than those in figure 2.

Figure 8 shows flow from a burner entering at a flow guide at the axle. No figure is drawn for how flow from a burner enters at the periphery of a pump.

Figure 9 shows the bearings to keep the axle from migrating relative to the casings.

Figure 10 and 11 shows cross-sections J, K, L, and M with flow and blade rotation for a multistage compressor.

Figure 12 shows four centrifugal pumps like the ones in figure 1. The cross-sections J, K, L, and M will show flow and blade rotation for a multistage compressor.

DETAILED DESCRIPTION OF THE INVENTION

[0080] First I will describe a series of centrifugal pumps used as an expander. Half the pumps have flow traveling from the periphery toward the axle. The other half of the pumps have flow traveling from near the axle to the periphery. There may be one extra pump of either flow type. Later I will describe the use of this multistage expander or any multistage expander as part of an internal combustion engine. After that I will describe its use in an external heat engine. Flow guides converting between axial and radial flow will also be discussed. Eventually a series of centrifugal pumps used as a compressor will be described. Half these compressor pumps have flow traveling from the periphery toward the axle. The other half of the compressors are conventional, having flow traveling from the axle to the periphery. The traveling of course is on a spiral path.

[0081] Note that the word expander includes the concept that heat energy and pressure energy and flow inertial energy of motion in a gas flowing through the expander is converted into mechanical energy The mechanical energy in the case of a centrifugal expander is received by a rotor pushed by the flow of the gas through the expander. The centrifugal pump and rotor could be replaced by another mechanical device such as a piston. Most often the temperature of the gas goes down in the interval between entering and leaving the expander. Most often the gas expands within the expander. The gas speed may increase in the interval between entering and leaving the expander. A centrifugal expander is defined as a centrifugal pump operated to act as an expander. In older art the centrifugal pump is mainly thought of as a compressor.

[0082] Figure 1 shows a workable, but simplified, version of a set of centrifugal expanders in series. Pump 10 and pump 20 are two centrifugal pumps, in this case expanders. They are connected in the sense of flow at the center near axle 50 by the paths between hourglass shaped substantially parallel flow guides 51. The flow guides are in most part locally substantially parallel but the distance between them can vary somewhat with position. In this case the flow guides divide the flow into several distinct paths. The flow guides rotate with the axle and are connected to each other by supports not shown that extend between nearest flow guides and can be used to maintain rotation of the flow. Some supports also extend from the axle to the nearest flow guide. Figure 2 is a blowup of the right center of figure 1. Figure 7 is an improvement on figure 2 showing better flow guides each with a larger turning radius.

[0083] The arrows in figures 3 and 4 show flow direction of the flow coming from the periphery of pump 10, passing along flow guides 51, and going to the periphery of pump 20. Figure 3, is cross-section A, and figure 4, is cross-section B, respectively of figure 1. The spirals of vanes attached to discs 13 and 14 and attached to disks 23 and 24 are also shown in figure 3 and 4 respectively. The discs 13 and 23 are attached to and rotate with the axle 50. All the rotation directions of the discs and of the vanes and of the flow guides are clockwise as shown by the little arrow near the center of figure 3 and the little arrow near the center of figure 4. Because the disks 13 and 23 are attached to the axle 50, they rotate at the same rate as the flow guides 51. For example disc 13 is attached at point 17. Discs 14 and 24 rotate because the rotation is carried from discs 13 and 23 by the vanes, sometimes called blades. The blades extend from one disc to the other and thus form channels extending from near the axle to near the periphery.

[0084] Note that in figures 3, 4, 10, and 11 the blades of the rotors are shown as lines spiraling from periphery toward center. It would be advantageous to introduce more blades between the shown blades especially near the periphery for flow reasons. For preventing eddy currents, due to centrifugal force and blade curvature, the distance between blades should be about one tenth of the curvature radius of the blades if the blades were not moving, but much more if the blades are causing centrifugal forces. For example, halfway to the periphery a new set of blades should be added extending to the periphery of the discs from the halfway point. This is shown in figures 3 and 4 but not in figures 10 and 11. Actually adding more blades is advantageous at all distances from the center. This has a practical limit because of the thickness and weight of blades. The weight limits ultimate speed because of centrifugal forces tending to pull the rotor apart. In further explanation of the benefit of more blades, the blades are moving and causing centrifugal force on the fluid. This force is proportional to the radius = distance from the axle center. This proportional force makes the extra blades near the periphery more important.

[0085] Note also that the inner third of the rotors provides only one ninth of the compression effect, because the compression rate per distance at a particular distance from the axle is proportional to radius. This is because the force is proportional to radius. Thus the inner third of the fluid flow space can be allocated to making a gentle turn from radial inward flow to radial outward flow as shown in figure 7.

[0086] Note that the discs, while shown as flat neither concave nor convex, in for example figure 1 can be shaped differently. For example, they may diverge from each other as they approach the center. They may diverge from each other as they approach the periphery. A pair of discs may both tend toward the direction of the flow guides as they approach the center, thus making the change of direction of the fluid within the flow guide region diminish.

[0087] Note that the sides of the discs opposite to the sides connected to the vanes may be insulated to keep the heat in the flow region. Of course all parts can be insulated to discourage losses due to heat traveling especially along the discs or vanes.

[0088] The close spacing of the flow guide parts discourages turbulence and studies have determined the best spacing. A ratio of 10:1 between the radius of curvature of the fluid path and the spacing across a flow between a flow guide part contacting fluid nearer to the axle than itself and a flow guide part contacting fluid further from the axle than itself is very adequate. An example of the above is tubes, all of which would have parts nearer the axle and parts further from the axle than the fluid contacted. If we are talking about flow guides similar to sheets, maybe varying a little in thickness then the spacing refers to that between sheets. If we are talking about using tubes as guides then the spacing across a flow between the flow guide parts refers to the inside diameter of the tubes.

[0089] Figure 1 is symmetrical around the axle 50, so the numbering of parts at the bottom is the same as the numbering at the top. The casing of the pumps consists of what can be a connected set of parts. Part 15 for pump 10, is not attached to the axle but comes very close to it at point 16, where a pressure seal may be placed. Part 15 also stretches across the periphery, at the top and bottom of the drawing. Casing part 60 which is common to pump 10 and pump 20 extends from the periphery to close to the nearest points to the flow guides, on discs 14 and 24. Discs 14 and 24 are connected together by part 61 near the hourglass shaped flow guides. Parts 11 and 21 are rings to inhibit flow from going outside the discs from near the periphery to near the axle. A better and second place to put rings extending between the discs and the casing is near the axle, as shown in figure 1 and figure 2, but there is a lot of clutter there in the drawing so those inner rings are not numbered. If friction is not too significant then the rings can touch both surfaces and a lubricant can be added. If the flow were to get near the axle it might go along the axle to another set of pumps, for example pumps 30 and 40. Parts 12 and 22 are rings to inhibit flow from going in the space between disc 14 and part 60 and between disc 24 and part 60, thus traveling between pump 10 and pump 20. These rings 12 and 22 could have been moved much closer to the axle, thus producing less torque per contact and less ring length. Notice that all discs are separated from the casing by a gas filled space. Thus for the blades, which are attached to and between the discs, and the discs themselves almost no moving part is near the casing. The discs have circular symmetry and thus their rotation will not cause significant eddy currents. Also remember that the word pump applies to an expander in the current discussion.

[0090] Of course part 60 could be two separate parallel parts. Also the casing may be formed in two or more parts with a gasket between them and bolted together. The gaskets could run parallel to the axle 50 so that the whole rotating assembly could be removed, refurbished and replaced.

[0091] Figure 2 shows a blown up portion of figure 1, which portion is to the right and centered on the axle 50. It shows point 16 where the casing is separate from the axle 50. It also shows point 17, where disc 13 is attached to the axle. To the left of figure 2, there is a cross-section E containing a set of bearings so that the axle can rotate inside a stationary casing. The bearing set and its casing are part 80, which is later further defined in figure 9. This part is solidly connected to casing part 25 and its counterpart on the next set of pumps 30 and 40. Pumps 30 and 40 can be described the same way as pumps 10 and 20.

[0092] The pumps although pictured as identical may vary in size, mainly the distance between discs, to allow for shrinking of the working gas as it cools. Also the radial dimensions may vary to keep pressure drop ratios to similar sizes in successive pumps. One order of visitation for the working gas may be from input at C to D to A to output at B. A, B, C, and D refer to the cross-sections of the various pumps. For simplicity I am naming the pumps by their cross-sections. Another way to put it is that input occurs at the periphery of pump 30. The flow then goes to the center and back to the periphery of pump 40. The flow then goes to the periphery of pump 10. The flow then goes to the center and back to the periphery of pump 20. The center is the closest point to the axle.

[0093] Another order would be input at A to B to C and output at D. The first order gives more distance to connect one pump set (of two) to the other set (of two) at their peripheries. Because all pump rotors on the same axle rotate clockwise, or all rotate counter, the output gas at the periphery of one pump set has to rotate 180 degrees before entering the next pump set at its periphery. This can also be seen in figures 3 and 4 by observing the arrow directions at the peripheries of pumps D and A or B and C.

[0094] If two or more axles are used, then if as in figure 5 both axles are rotating clockwise then the gas can travel as shown in figure 5 between pumps one on each axle. If for gyroscopic reasons you prefer to have the axles rotate in opposite directions then the gas can travel as in figure 6 and connect so that the flows are both spinning clockwise even though the rotor in sections like B and D are rotating counter-clockwise, which is opposite to the gas inertial rotation, because of conservation of angular momentum. If four axles are used, then the engine would be very compact having maybe 16 pumps in sets of four each set. A set of four pumps is shown in figure 1. If you look at adiabatic expansion formulae, then it takes four times as many stages, giving four times the pressure ratio to get the same total temperature ratio for triatomic gases, like CO_2, than it takes for a monatomic gas, like Argon. Since air is 80% N_2 we are more concerned with diatomic gases. It takes two times as many stages, giving two times the pressure ratio to get the same total temperature ratio for diatomic gases, like N_2, than it takes for a monatomic gas, like Argon.

[0095] For examples of compressor ratios per stage see the web site of compressor builder Elliott. I am not allowed to say how many stages it takes to reach a compression ratio of 6:1 for argon or 12:1 for air using normal steel construction, but there are apps on their web site, Elliott-turbo, to calculate the number of stages recommended. For my stages I get useful expansion or compression every time the working gas goes from periphery to center and every time the working gas goes from center to periphery. The Elliot design gets compression only on the path from center to periphery and the gas is then brought back to the center along stationary channels. With enough stages any compression ratio can be reached. One goal is to produce a temperature ratio at each stage and eventually get a temperature ratio of 2 or greater. This would translate to 50% efficiency, minus losses. Expansion ratios are similar to get the 2:1 temperature ratio in the opposite direction. Again by the adiabatic formulae, it takes a 6:1 pressure ratio in argon and a 12:1 ratio in air to get the 2:1 temperature ratio.

[0096] Notice that figure 1 can continue to the right or left, adding more pumps and "ball" bearing structures. The bearings need not be balls, but could be cylinders or maybe magnetic or hydraulic bearings, etc.

[0097] Figure 7 is an improvement to figure 2 and shows a set of flow guides 151 replacing flow guides 51 and rounded connector 161 replacing straight connector 61 connecting discs 14 and 24. The part of the casing common to the two pumps is now called part 160. The improvement gives much less pressure loss during flow near the axle.

[0098] Turning now to Figure 8, I will discuss an engine using internal combustion to produce heated gas or using compressed air and solar power to produce heated gas which is then introduced into a multistage expander part of the engine. Note that the upper temperature of the heated gas can be regulated even if the heat is caused by combustion. For example if air, having been compressed, is being introduced, using more air than necessary for combustion, as would happen if the mixture is lean, can lower the gas temperature before introducing the gas into the expander. Since engine efficiency depends on temperature ratio, then the necessary temperature for 50 % efficiency would be a little more than double the atmospheric temperature. For better than 50% efficiency the input temperature and the number of expansion stages could be increased Adding more air can actually increase efficiency, because O_2 and N_2 are diatomic needing less compression ratio than a triatomic gas to obtain the same temperature change in an adiabatic expansion. CO_2 and H_2O, are triatomic and products of combustion. Also for a given number of expanders, the amount of heat thrown away will be much less for lower starting and ending temperatures.

[0099] The new expander has been discussed above and shown in the first seven figures. If desired, the source of heated gas can cause flow to enter near the axle. For example, in figure 1 the pump 10 can be removed and the right half of flow guides 51 would be gone. Flow would enter traveling toward the left into the paths between the remaining halves of the flow guides, as shown in figure 8.

[0100] Figure 8 shows the new look of the center, corresponding to figure 7, with heated gases being introduced from the right. Figure 7 is similar to the central and right side part of figure 1. In figure 8, parts 176 and 175 are parts of a source of combustion gases or a source of heated gases. The source 178 could be similar to a small jet engine or it could be simply a combustion chamber with means to inject fuel and air or it could be any source of combustion gases under pressure. Alternately, it could be a source into which air is injected under pressure and in which the air is heated by solar means or by heat exchange using a flow from a nuclear reactor or by other means. Part 175 is attached to casing part 160, which is one part of a pump casing. Part 160 was the common part of two pump casings but one pump has been removed to be replaced by the source of combustion gases 178. Part 124 is the right disc of a rotor. The arrows show combustion gases entering the flow guides 151 from source 178. Pointed splitter 179 is attached to the axle to smooth flow from the source to the guides. Part 176 was added to smooth flow to the guides, and maybe also to insulate part 175 from the intense heat. Figure 8 is only part of the engine and continues to the left, to the right, toward the top and toward the bottom of the figure. It mainly shows how the combustion gases enter the engine.

[0101] If desired, the heated gases can enter at the periphery of one of the pumps. The periphery and the opening are shown in figure 3, where flow proceeds from the periphery toward the axle. Note the arrows in figure 3 showing flow entering tangentially at the periphery at the top of the figure. The source of combustion gases is not shown but would be connected in an obvious way to the tube at the periphery of the pump stage.

[0102] The multistage pump fed by heated pressurized gas, consisting of multiple single stage pumps connected in series and used in the engine described above need not be similar to mine. It may be more similar to the pumps shown on the Elliott-turbo site, producing power only on the trips where the gas is expanding while traveling toward the periphery. The trip back to the center before the next stage is not producing output energy in the Elliott-turbo site pumps. Also note that the Elliott site pumps, also called compressors, are compressors not expanders. However, the compressors could be used in reverse with a little extra engineering to produce expanders.

[0103] Before leaving figure 8, it should be mentioned that the gas is injected from the right axially, meaning flow parallel to the axle, with very little if any radial motion, meaning motion perpendicular to the axle. The gas is guided by flow guides 151 so that the gas leaving the flow guides is traveling with small or zero axial motion but with significant radial spiraling motion. Notice that each guide has substantial surface area. The guides as a group could be described as a means consisting of several solid nearly rigid sheets locally substantially parallel to each other the means serving the purpose of converting axial flow to substantially radial spiraling flow.

[0104] Similarly figure 7 shows the set of flow guides 151 before the right half was cut off. The uncut flow guides convert gas flow injected from one pump substantially toward the axle, to gas flow substantially along the axle and then to gas flow leaving the guides substantially toward the periphery of a second pump in a substantially radial direction. The guides in this case could be described as a means consisting of several solid nearly rigid sheets locally substantially parallel to each other the means serving the purpose of converting substantially radial spiraling flow to axial flow and then to substantially radial spiraling flow. The travel is first toward the axle and eventually away from the axle.

[0105] Figure 9 shows one of many possible cross-sections E. Ring 81 is a bridge part between two pump casings and firmly attached to the casings. It may be two halves of a ring, since the casings will probably also be two halves separated by gaskets parallel to the axle and bolted together. Ring 82 is a raceway for the ball bearings and will attach to ring 81. Ball bearings 83 ride in the raceway and also contact the axle. The assembly consisting of ring 82 and bearings 83 is like many ball bearing assemblies currently capable of being manufactured. The axial and radial forces and what kind of raceway is attached to the axle will be left to the engineers. As stated previously other types of bearing assemblies may be used including magnetic. For clarity of illustration of function I chose to show ball bearings so the figures could be understood without words.

[0106] I will now discuss the multistage compressor. Figures 10 and 11 are the cross-sections for parts of the pump stages in the multistage compressor shown in figure 12. The whole multistage compressor is analogous to the multistage expander shown in figure 1. Notice that the figures 10 and 11 are copies of figures 3 and 4, except for the following. The flow and rotation arrows are in different directions and the extra blades are not added at the periphery and the figure captions are different. There could be extra blades added. Figure 12 shows, for the multistage compressor, the pump casings, the flow guides and the vane supporting discs but not the vanes. Thus it is almost identical to figure 1, except that the cross-sections are denoted by different letters.

[0107] I am now about to discuss centrifugal compressors, some with flow going from center to periphery as is in current art. Some other centrifugal compressors, new art, have flow going from periphery to center. The main attribute of a compressor is that it converts mechanical energy to energy in the gas being partly in pressure above ambient partly in heat energy and partly in flow velocity energy of the gas flowing through the compressor. Most often the temperature of the gas goes up in the interval between entering and leaving the compressor. Most often the gas contracts within the compressor, hence the word compressor.

[0108] Figure 12 shows a workable, but simplified, version of a set of centrifugal compressors in series. The numbering is the same as in figure 1, since the same parts pictured can be used in either a compressor or an expander. Pump 10 and pump 20 are two centrifugal pumps. In this case the pumps are compressors. They are connected in the sense of flow at the center near axle 50 by the paths between hourglass shaped flow guides 51. The flow guides rotate with the axle and are connected to each other by supports not shown that extend between nearest flow guides and can, but need not, be used to maintain rotation of the flow. Some supports also extend from the axle to the nearest flow guide. Figure 2 is a blowup of the right center of figure 12. Figure 7 is an improvement on figure 2 showing better flow guides.

[0109] The arrows in figures 10 and 11 show flow direction of the flow coming from the periphery of pump 10, passing along flow guides 51, and going to the periphery of pump 20. Figure 10, is cross-section J, and figure 11, is cross-section K, respectively of figure 12. The spirals of vanes attached to discs 13 and 14 and attached to disks 23 and 24 are also shown in figure 10 and 11 respectively. The discs 13 and 23 are attached to and rotate with the axle 50. All the rotation directions of the discs and of the vanes and of the flow guides are counter-clockwise as shown by the little arrow near the center of figure 10 and the little arrow near the center of figure 11. Because the disks 13 and 23 are attached to the axle 50, they rotate at the same rate as the flow guides 51. For example disc 13 is attached at point 17. Discs 14 and 24 rotate because the rotation is carried from discs 13 and 23 by the vanes, sometimes called blades. The blades extend from one disc to the other and thus form channels extending from near the axle to near the periphery.

[0110] The close spacing of the flow guides discourages turbulence and studies have determined the best spacing. A ratio of 10:1 between the radius of curvature of the fluid path and the spacing between flow guides is very adequate. Figure 1 is symmetrical around the axle 50, so the numbering of parts at the bottom is the same as the numbering at the top. The discussion of the pump casings and other aspects of figure 1 apply to figure 12.

Claims

1. A multistage expander or compressor comprising at least one set of stages (10, 20. 30, 40),
an output flow from a first member of said set flowing into a second member of said set, each member of said set sending its output flow into its successor until the last in the succession,
at least one stage (10, 20, 30, 40) of said set having the majority of flow travelling within it spiralling inward from nearer a periphery to nearer an axis of rotation of a rotor of said set,
at least one other stage (10, 20, 30, 40) of said set having the majority of flow travelling within it spiralling outward from nearer the axis of rotation of the rotor to nearer the periphery of this rotor,
characterised in that the at least one stage (10, 20, 30, 40) has means to cause angular velocity around said axis of rotation of substantially all of said flow entering from outside a space swept by said rotor to be in the same direction for the expander and in the opposite direction for the compressor, the two directions being clockwise and counter-clockwise, with respect to the angular velocity of its rotor vanes, the two angular velocities being each of substantial magnitude;
said at least one other stage (10, 20, 30, 40) of said set has means to cause angular velocity of most of said flow around said axis of rotation in the vicinity of but barely outside the space swept by said rotor to be in the opposite direction for the expander and in the same direction for the compressor, with respect to the angular velocity of its rotor vanes, the two directions being clockwise and counter-clockwise, the two angular velocities for flow and for rotor vanes respectively each being of substantial magnitude and each being around said axis of rotation.

2. The multistage expander or compressor of claim 1 wherein the rotor of said at least one stage (10, 20, 30, 40) and the rotor of said at least one other stage (10, 20, 30, 40) are on the same axle (50), or the rotor of said at least one stage (10, 20, 30, 40) and the rotor of said at least one other stage (10, 20, 30, 40) are on two separate axes of rotation spaced apart but substantially alongside each other.

3. The multistage expander or compressor of claim 1 wherein the radial size of the rotor of said at least one stage (10, 20, 30, 40) and the radial size of the rotor of said at least one other stage (10, 20, 30, 40) are different.

4. An engine usable to convert heat energy into mechanical motion energy by expansion of a hot gas, comprising the multistage expander or compressor of claim 1, said engine comprising means to introduce hot gas into the expander, the hot gas being under pressure, the introduced gas leaving the engine after passing through the expander.

5. The engine of claim 4 wherein said hot gas under pressure is produced by combustion or by using a heat exchanger deriving the heat from an external source.

6. The engine of claim 4 wherein the hot gas under pressure is introduced into said multistage centrifugal expander from outside the multistage expander at a place nearer the axle (50) of the stage (10, 20, 30, 40) used as an expander than the periphery of that stage used as an expander, or at a place nearer the periphery of the stage used as an expander than the axle (50) of that stage (10, 20, 30, 40) used as an expander.

7. A heat pump or an engine comprising the multistage expander or compressor of claim 1, to convert between heat energy and motion energy and said heat pump or engine further comprises a multistage centrifugal compressor.

8. The heat pump or engine of claim 7 wherein the rotors of said set of successive centrifugal stages used as expanders and the rotors of said multistage centrifugal compressor are all surrounded by the flow of gas within the heat pump or engine, said flow being unidirectional and all parts of the flow communicating with each other, using a route of communication going through at least one centrifugal stage (10, 20, 30, 40).

9. A heat pump or an engine comprising the multistage expander or compressor of claim 1 to convert between heat energy and motion energy, said heat pump or engine further comprising a multistage centrifugal expander, and the output from said multistage centrifugal compressor eventually going into said multistage centrifugal expander.

10. The heat pump or expander of claim 9 wherein the rotors of said set of centrifugal stages (10, 20, 30, 40) used as compressors and the rotors of said multistage centrifugal expander are all surrounded by the flow of gas within the device, said flow being unidirectional and all parts of the flow communicating with each other, using a route of communication going through at least one centrifugal stage (10, 20, 30, 40), the output from said multistage centrifugal expander eventually going into said multistage centrifugal compressor.

11. The multistage expander or compressor of claim 1 wherein the multistage expander or compressor further comprise a set of flow guides (51, 151), the guides being nearly rigid solid bodies, the guides (51,

151) helping to change the direction of flow of a gas between a state of being substantially parallel to an axle (50) of a rotor with almost no flow moving perpendicular to the axle (50) of said rotor and a state of the flow being substantially spiralling around that axle (50), the guides (51, 151) being used to do the flow direction changes with less eddy currents than if the flow guides were removed thus requiring the flow to use less channels.

12. The multistage expander or compressor of claim 11 wherein said set of flow guides (5 1, 151) is comprised of substantially like sheets that are in the most part locally substantially parallel to the nearest neighbouring guide, or are similar to a set of tubes running locally parallel to the preferred flow lines for said gas.

13. The multistage expander or compressor of claim 11 wherein said set of flow guides (51, 151) is attached to said axle (50) and thus rotating with the axle (50).

14. The multistage expander or compressor of claim 11 wherein the said flow of gas is first spiralling substantially toward the axle (50) and it enters the region of said set of flow guides (51, 151) which help to convert the spiralling motion to axial motion, which is by definition substantially parallel to the axle, or the said flow of gas is first in a state of axial motion being substantially parallel to the axle and then it enters said set of flow guides (51, 151) which help to convert the axial motion substantially parallel to the axle (50) to motion substantially spiralling away from the axle (50).

15. The multistage expander or compressor of claim 11 wherein the said gas is first spiralling substantially toward the axle (50) and it enters said set of flow guides (51, 151) which help in converting the spiralling motion to axial motion parallel to the axle (50), and then further the guides also help in converting the axial motion of the gas substantially parallel to the axle (50) to motion substantially spiralling away from the axle (50), parts of the flow communicating with each other using a route of communication going through part of at least one centrifugal stage (10, 20, 30, 40).

Patentansprüche

1. Mehrstufiger Expander oder Kompressor, der wenigstens einen Satz Stufen (10, 20, 30, 40) aufweist, wobei ein Ausgangsstrom von einem ersten Element des genannten Satzes in ein zweites Element des genannten Satzes strömt, wobei jedes Element des genannten Satzes seinen Ausgangsstrom jeweils in seinen Nachfolger schickt, bis zum Letzten in der Reihenfolge,
wobei bei wenigstens einer Stufe (10, 20, 30, 40) des genannten Satzes der Großteil von sich in ihm bewegenden Strom sich spiralig einwärts von näher an einem Umfang zu näher an einer Drehachse eines Rotors des genannten Satzes bewegt,
wobei bei wenigstens einer Stufe (10, 20, 30, 40) des genannten Satzes der Großteil von sich in ihm bewegenden Strom sich spiralig auswärts von näher an der Drehachse des Rotors zu näher an dem Umfang dieses Rotors bewegt,
dadurch gekennzeichnet, dass die wenigstens eine Stufe (10, 20, 30, 40) ein Mittel zum Veranlassen hat, dass eine Winkelgeschwindigkeit um die genannte Drehachse des im Wesentlichen ganzen genannten Stroms, der von außerhalb eines von dem genannten Rotor bestrichenen Bereichs her einströmt, für den Expander in der gleichen Richtung und für den Kompressor in der entgegengesetzten Richtung ist, wobei die zwei Richtungen der Uhrzeigersinn und entgegen dem Uhrzeigersinn in Bezug auf die Winkelgeschwindigkeit ihrer Rotorschaufeln sind, wobei die zwei Winkelgeschwindigkeiten jeweils von beträchtlicher Größe sind;
die genannte wenigstens eine weitere Stufe (10, 20, 30, 40) des genannten Satzes ein Mittel zum Veranlassen hat, dass die genannte Winkelgeschwindigkeit des Meisten des genannten Stroms um die genannte Drehachse in der Nähe, aber kaum außerhalb des von dem genannten Rotor bestrichenen Bereichs für den Expander in der entgegengesetzten Richtung und für den Kompressor in der gleichen Richtung in Bezug auf die Winkelgeschwindigkeit ihrer Rotorschaufeln ist, wobei die zwei Richtungen der Uhrzeigersinn und entgegen dem Uhrzeigersinn sind, wobei die zwei Winkelgeschwindigkeiten für den Strom bzw. für die Rotorschaufeln jeweils von beträchtlicher Größe sind und jeweils um die genannte Drehachse sind.

2. Mehrstufiger Expander oder Kompressor nach Anspruch 1, wobei der Rotor der genannten wenigstens einen Stufe (10, 20, 30, 40) und der Rotor der genannten wenigstens einen weiteren Stufe (10, 20, 30, 40) auf der gleichen Achse (50) sind oder der Rotor der genannten wenigstens einen Stufe (10, 20, 30, 40) und der Rotor der genannten wenigstens einen weiteren Stufe (10, 20, 30, 40) auf zwei separaten Drehachsen sind, die voneinander beabstandet, aber im Wesentlichen nebeneinander sind.

3. Mehrstufiger Expander oder Kompressor nach Anspruch 1, wobei die radiale Größe des Rotors der genannten wenigstens einen Stufe (10, 20, 30, 40) und die radiale Größe des Rotors der genannten wenigstens einen weiteren Stufe (10, 20, 30, 40) verschieden sind.

4. Maschine, verwendbar zum Umwandeln von Wärmeenergie in mechanische Bewegungsenergie durch Expansion eines Heißgases, die den mehrstufigen Expander oder Kompressor nach Anspruch 1 aufweist, wobei die genannte Maschine ein Mittel zum Einführen von Heißgas in den Expander aufweist, wobei das Heißgas unter Druck ist, wobei das eingeführte Gas die Maschine nach Durchlaufen des Expanders verlässt.

5. Maschine nach Anspruch 4, wobei das genannte Heißgas unter Druck durch Verbrennung oder durch Verwendung eines Wärmetauschers, der die Wärme aus einer externen Quelle herleitet, erzeugt wird.

6. Maschine nach Anspruch 4, wobei das Heißgas unter Druck von außerhalb des mehrstufigen Expanders an einer Stelle, die näher an der Achse (50) der als Expander verwendeten Stufe (10, 20, 30, 40) als am Umfang dieser als Expander verwendeten Stufe liegt, oder an einer Stelle, die näher am Umfang der als Expander verwendeten Stufe als an der Achse (50) dieser als Expander verwendeten Stufe (10, 20, 30, 40) liegt, in den genannten mehrstufigen Zentrifugalexpander eingeführt wird.

7. Wärmepumpe oder Maschine, die den mehrstufigen Expander oder Kompressor nach Anspruch 1 aufweist, zum Umwandeln zwischen Wärmeenergie und Bewegungsenergie und wobei die genannte Wärmepumpe oder Maschine ferner einen mehrstufigen Zentrifugalkompressor aufweist.

8. Wärmepumpe oder Maschine nach Anspruch 7, wobei die Rotoren des genannten Satzes aufeinanderfolgender Stufen, die als Expander verwendet werden, und die Rotoren des genannten mehrstufigen Zentrifugalkompressors alle vom Gasstrom innerhalb der Wärmepumpe oder Maschine umgeben sind, wobei der genannte Strom unidirektional ist und alle Teile des Stroms miteinander in Strömungsverbindung sind, wobei sie einen Strömungsverbindungsweg verwenden, der durch wenigstens eine Zentrifugalstufe (10, 20, 30, 40) verläuft.

9. Wärmepumpe oder Maschine, die den mehrstufigen Expander oder Kompressor nach Anspruch 1 aufweist, zum Umwandeln zwischen Wärmeenergie und Bewegungsenergie, wobei die genannte Wärmepumpe oder Maschine ferner einen mehrstufigen Zentrifugalexpander aufweist und die Ausgabe vom genannten mehrstufigen Zentrifugalkompressor schließlich in den genannten mehrstufigen Zentrifugalexpander gelangt.

10. Wärmepumpe oder Maschine nach Anspruch 9, wobei die Rotoren des genannten Satzes Zentrifugalstufen (10, 20, 30, 40), die als Kompressoren verwendet werden, und die Rotoren des genannten mehrstufigen Zentrifugalexpanders alle vom Gasstrom innerhalb der Vorrichtung umgeben sind, wobei der genannte Strom unidirektional ist und alle Teile des Stroms miteinander in Strömungsverbindung sind, wobei sie einen Strömungsverbindungswegs verwenden, der durch wenigstens eine Zentrifugalstufe (10, 20, 30, 40) verläuft, wobei die Ausgabe vom genannten mehrstufigen Zentrifugalexpander schließlich in den genannten mehrstufigen Zentrifugalkompressor gelangt.

11. Mehrstufiger Expander oder Kompressor nach Anspruch 1, wobei der mehrstufige Expander oder Kompressor ferner einen Satz Strömungsleitelemente (51, 151) aufweist, wobei die Leitelemente fast starre feste Körper sind, wobei die Leitelemente (51, 151) zum Ändern der Strömungsrichtung eines Gases zwischen einem zu einer Achse (50) eines Rotors im Wesentlichen parallelen Zustand, bei dem fast kein Strom lotrecht zur Achse (50) des genannten Rotors strömt, und einem Zustand, in dem sich der Strom im Wesentlichen spiralig um diese Achse (50) bewegt, beitragen, wobei die Leitelemente (51, 151) verwendet werden, um die Strömungsrichtungsänderungen mit weniger Wirbelströmungen durchzuführen, als wenn die Strömungsleitelemente entfernt wären, so dass der Strom weniger Kanäle verwenden muss.

12. Mehrstufiger Expander oder Kompressor nach Anspruch 11, wobei der genannte Satz Strömungsleitelemente (51, 151) sich aus im Wesentlichen gleichen Blechen zusammensetzt, die zum großen Teil lokal im Wesentlichen parallel zu dem am Nächsten liegenden benachbarten Leitelement sind, oder einem Satz Rohren ähnlich sind, die lokal parallel zu den bevorzugten Strömungslinien für das genannte Gas verlaufen.

13. Mehrstufiger Expander oder Kompressor nach Anspruch 11, wobei der genannte Satz Strömungsleitelemente (51, 151) an der genannten Achse (50) angebracht ist und sich daher mit der Achse (50) dreht.

14. Mehrstufiger Expander oder Kompressor nach Anspruch 11, wobei der genannte Gasstrom sich zunächst spiralig im Wesentlichen zur Achse (50) hin bewegt und in die Region des genannten Satzes Strömungsleitelemente (51, 151) eintritt, die zum Umwandeln der spiraligen Bewegung in die axiale Bewegung, die definitionsgemäß im Wesentlichen parallel zur Achse ist, beitragen, oder der genannte Gasstrom zunächst in einem Zustand axialer Bewegung ist, die im Wesentlichen parallel zur Achse ist, und dann in den genannten Satz Strömungsleitelemente (51, 151) eintritt, die zum Umwandeln der zur Achse (50) im Wesentlichen parallelen axialen Bewegung in eine Bewegung, die sich von der Achse (50) im Wesentlichen spiralig wegbewegt, beitragen.

15. Mehrstufiger Expander oder Kompressor nach Anspruch 11, wobei das genannte Gas sich zunächst im Wesentlichen spiralig zur Achse (50) hin bewegt und in den genannten Satz Strömungsleitelemente (51, 151) eintritt, die zum Umwandeln der spiraligen Bewegung in eine axiale Bewegung, die parallel zur Achse ist, beitragen, und dann die Leitelemente ferner auch zum Umwandeln der axialen Bewegung des Gases, die im Wesentlichen parallel zur Achse (80) ist, in eine Bewegung, die sich im Wesentlichen spiralig von der Achse (50) weg bewegt, beitragen, wobei Teile des Stroms miteinander unter Verwendung eines Strömungsverbindungswegs, der durch wenigstens eine Zentrifugalstufe (10, 20, 30, 40) verläuft, in Strömungsverbindung sind.

Revendications

1. Détendeur ou compresseur à étages multiples comprenant au moins un ensemble d'étages (10, 20, 30, 40),
un flux de sortie provenant d'un premier élément dudit ensemble qui s'écoule dans un deuxième élément dudit ensemble, chaque élément dudit ensemble envoyant son flux de sortie dans son successeur jusqu'au dernier dans la succession,
au moins un étage (10, 20, 30, 40) dudit ensemble dont la majorité du flux qui circule en son sein suit une spirale vers l'intérieur à partir d'une partie plus proche d'une périphérie jusqu'à une partie plus proche d'un axe de rotation d'un rotor dudit ensemble,
au moins un autre étage (10, 20, 30, 40) dudit ensemble dont la majorité du flux qui circule en son sein suit une spirale vers l'extérieur à partir d'une partie plus proche de l'axe de rotation du rotor jusqu'à une partie plus proche de la périphérie de ce rotor,
caractérisé en ce que l'au moins un étage (10, 20, 30, 40) possède des moyens pour provoquer une vitesse angulaire autour dudit axe de rotation de substantiellement la totalité dudit flux arrivant à partir de l'extérieur d'un espace balayé par ledit rotor afin d'être dans le même sens pour le détendeur et dans le sens opposé pour le compresseur, les deux sens étant le sens horaire et le sens anti-horaire, par rapport à la vitesse angulaire de ses ailettes de rotor, les deux vitesses angulaires ayant chacune une ampleur substantielle ;
ledit au moins un autre étage (10, 20, 30, 40) dudit ensemble possède des moyens pour provoquer une vitesse angulaire de la plupart dudit flux autour dudit axe de rotation dans le voisinage de mais à peine à l'extérieur de l'espace balayé par ledit rotor afin d'être dans le sens opposé pour le détendeur et dans le même sens pour le compresseur, par rapport à la vitesse angulaire de ses ailettes de rotor, les deux sens étant le sens horaire et le sens anti-horaire, les deux vitesses angulaires pour le flux et pour les ailettes de rotor ayant respectivement chacune une ampleur substantielle et chacune ayant lieu autour dudit axe de rotation.

2. Détendeur ou compresseur à étages multiples de la revendication 1 dans lequel le rotor dudit au moins un étage (10, 20, 30, 40) et le rotor dudit au moins un autre étage (10, 20, 30, 40) se trouvent sur le même essieu (50), ou le rotor dudit au moins un étage (10, 20, 30, 40) et le rotor dudit au moins un autre étage (10, 20, 30, 40) se trouvent sur des axes de rotation séparés qui sont en espacement mais substantiellement le long l'un de l'autre.

3. Détendeur ou compresseur à étages multiples de la revendication 1 dans lequel la taille radiale du rotor dudit au moins un étage (10, 20, 30, 40) et la taille radiale du rotor dudit au moins un autre étage (10, 20, 30, 40) sont différentes.

4. Moteur utilisable pour convertir l'énergie thermique en énergie motrice mécanique grâce à l'expansion d'un gaz chaud, comprenant le détendeur ou compresseur à étages multiples de la revendication 1, ledit moteur comprenant des moyens pour introduire le gaz chaud dans le détendeur, le gaz chaud étant sous pression, le gaz introduit quittant le moteur après avoir traversé le détendeur.

5. Moteur de la revendication 4 dans lequel ledit gaz chaud sous pression est produit par combustion ou par l'utilisation d'un échangeur de chaleur dérivant la chaleur à partir d'une source externe.

6. Moteur de la revendication 4 dans lequel le gaz chaud sous pression est introduit dans ledit détendeur centrifuge à étages multiples à partir de l'extérieur du détendeur à étages multiples au niveau d'un endroit plus proche de l'essieu (50) de l'étage (10, 20, 30, 40) utilisé en tant que détendeur que la périphérie de cet étage utilisé en tant que détendeur, ou au niveau d'un endroit plus proche de la périphérie de l'étage utilisé en tant que détendeur que l'essieu (50) de cet étage (10, 20, 30, 40) utilisé en tant que détendeur.

7. Pompe à chaleur ou moteur comprenant le détendeur ou compresseur à étages multiples de la revendication 1, pour effectuer la conversion entre l'énergie thermique et l'énergie motrice et ladite pompe à chaleur ou ledit moteur comprenant en outre un compresseur centrifuge à étages multiples.

8. Pompe à chaleur ou moteur de la revendication 7 dans lequel les rotors dudit ensemble d'étages centrifuges successifs utilisés en tant que détendeurs et les rotors dudit compresseur centrifuge à étages multiples sont tous entourés du flux de gaz au sein de la pompe à chaleur ou du moteur, ledit flux étant unidirectionnel et toutes les parties du flux étant en communication les unes avec les autres, grâce à l'utilisation d'un trajet de communication traversant au moins un étage centrifuge (10, 20, 30, 40).

9. Pompe à chaleur ou moteur comprenant le détendeur ou compresseur à étages multiples de la revendication 1 pour effectuer la conversion entre l'énergie thermique et l'énergie motrice, ladite pompe à chaleur ou ledit moteur comprenant en outre un détendeur centrifuge à étages multiples, et la sortie provenant dudit compresseur centrifuge à étages multiples se rendant en fin de compte dans ledit détendeur centrifuge à étages multiples.

10. Pompe à chaleur ou détendeur de la revendication 9 dans lequel les rotors dudit ensemble d'étages centrifuges (10, 20, 30, 40) utilisés en tant que compresseurs et les rotors dudit détendeur centrifuge à étages multiples sont tous entourés du flux de gaz au sein du dispositif, ledit flux étant unidirectionnel et toutes les parties du flux étant en communication les unes avec les autres, grâce à l'utilisation d'un trajet de communication traversant au moins un étage centrifuge (10, 20, 30, 40), la sortie provenant dudit détendeur centrifuge à étages multiples se rendant en fin de compte dans ledit compresseur centrifuge à étages multiples.

11. Détendeur ou compresseur à étages multiples de la revendication 1 le détendeur ou compresseur à étages multiples comprenant en outre un ensemble de guides de flux (51, 151), les guides étant presque des corps pleins rigides (51, 151) qui aident à changer le sens de flux d'un gaz entre un état où il est substantiellement parallèle à un essieu (50) d'un rotor avec pratiquement aucun flux qui se déplace dans le plan perpendiculaire à l'essieu (50) dudit rotor et un état du flux qui est substantiellement en spirale autour de cet essieu (50), les guides (51, 151) étant utilisés pour réaliser les changements de sens de flux avec moins de courants de Foucault que si les guides de flux étaient enlevés ce qui obligerait le flux à utiliser moins de canaux.

12. Détendeur ou compresseur à étages multiples de la revendication 11 dans lequel ledit ensemble de guides de flux (51, 151) se compose substantiellement d'éléments ressemblant substantiellement à des feuilles qui sont pour la plupart substantiellement parallèles localement au guide avoisinant le plus proche, ou sont similaires à un ensemble de tubes s'étendant en parallèle localement aux lignes de flux préférées pour ledit gaz.

13. Détendeur ou compresseur à étages multiples de la revendication 11 dans lequel ledit ensemble de guides de flux (51, 151) est attaché audit essieu (50) est de ce fait tourne avec l'essieu (50).

14. Détendeur ou compresseur à étages multiples de la revendication 11 dans lequel ledit flux de gaz se déplace d'abord substantiellement en spirale vers l'essieu (50) et il entre dans la région dudit ensemble de guides de flux (51, 151) lesquels aident à convertir le mouvement en spirale en un mouvement axial, qui est par définition substantiellement parallèle à l'essieu, ou ledit flux de gaz se trouve d'abord dans un état de mouvement axial qui est substantiellement parallèle à l'essieu et ensuite il entre dans ledit ensemble de guides de flux (51, 151) qui aident à convertir le mouvement axial substantiellement parallèle à l'essieu (50) en un mouvement substantiellement en spirale s'éloignant de l'essieu (50).

15. Détendeur ou compresseur à étages multiples de la revendication 11 dans lequel ledit gaz se déplace d'abord en spirale substantiellement vers l'essieu (50) et il entre dans ledit ensemble de guides de flux (51, 151) lesquels aident à convertir le mouvement en spirale en un mouvement axial parallèle à l'essieu (50), et puis en outre les guides aident aussi à convertir le mouvement axial du gaz substantiellement parallèle à l'essieu (50) en un mouvement substantiellement en spirale s'éloignant de l'essieu (50), des parties du flux en communication les unes avec les autres utilisant un trajet de communication traversant une partie d'au moins un étage centrifuge (10, 20, 30, 40).

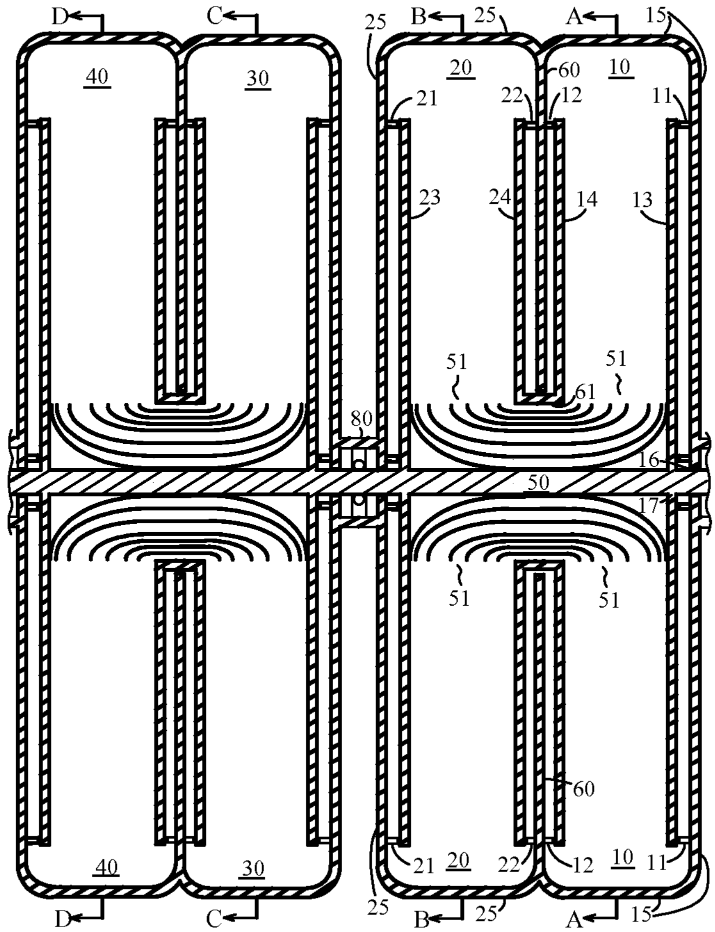

FIGURE 1

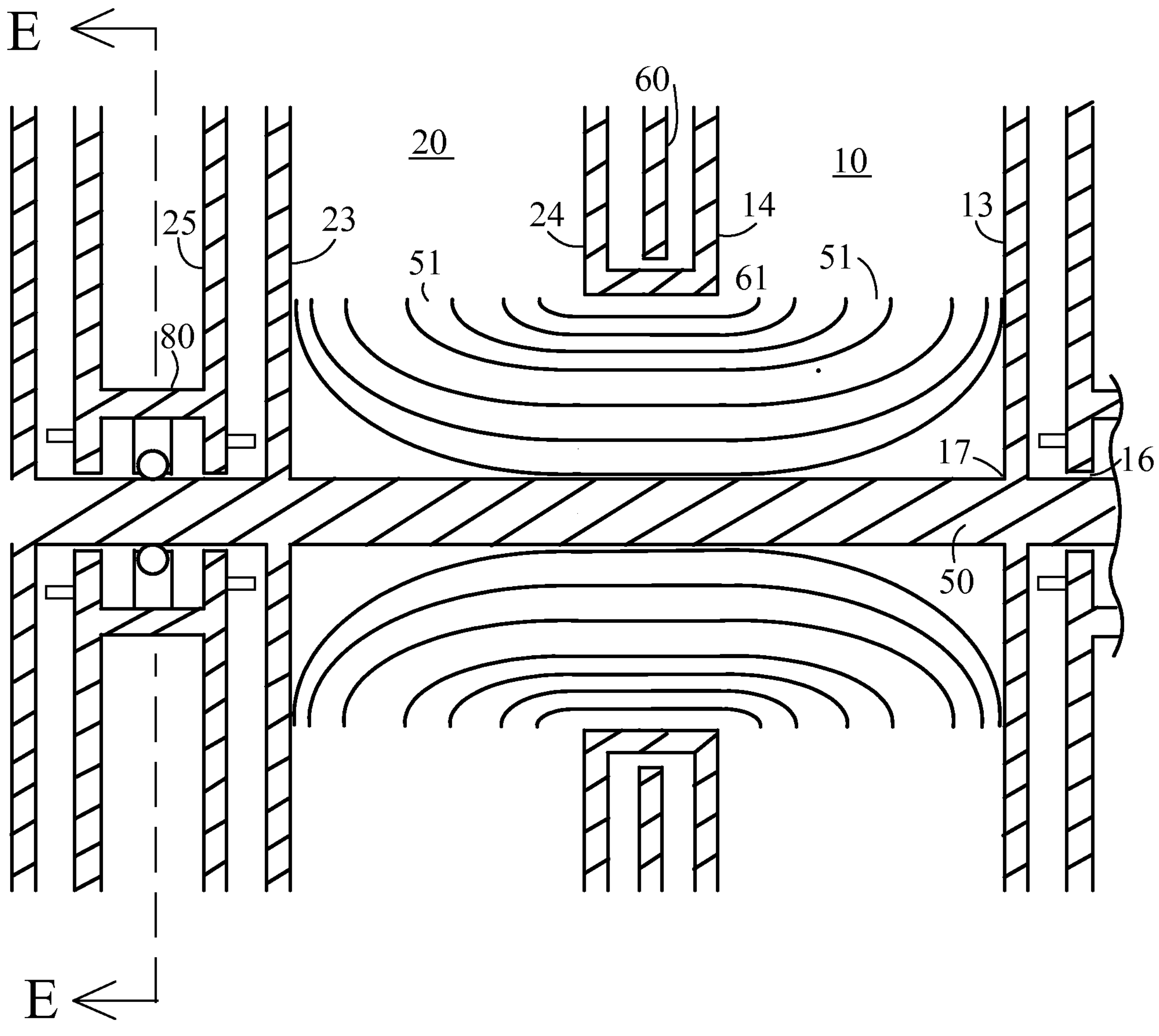

FIGURE 2

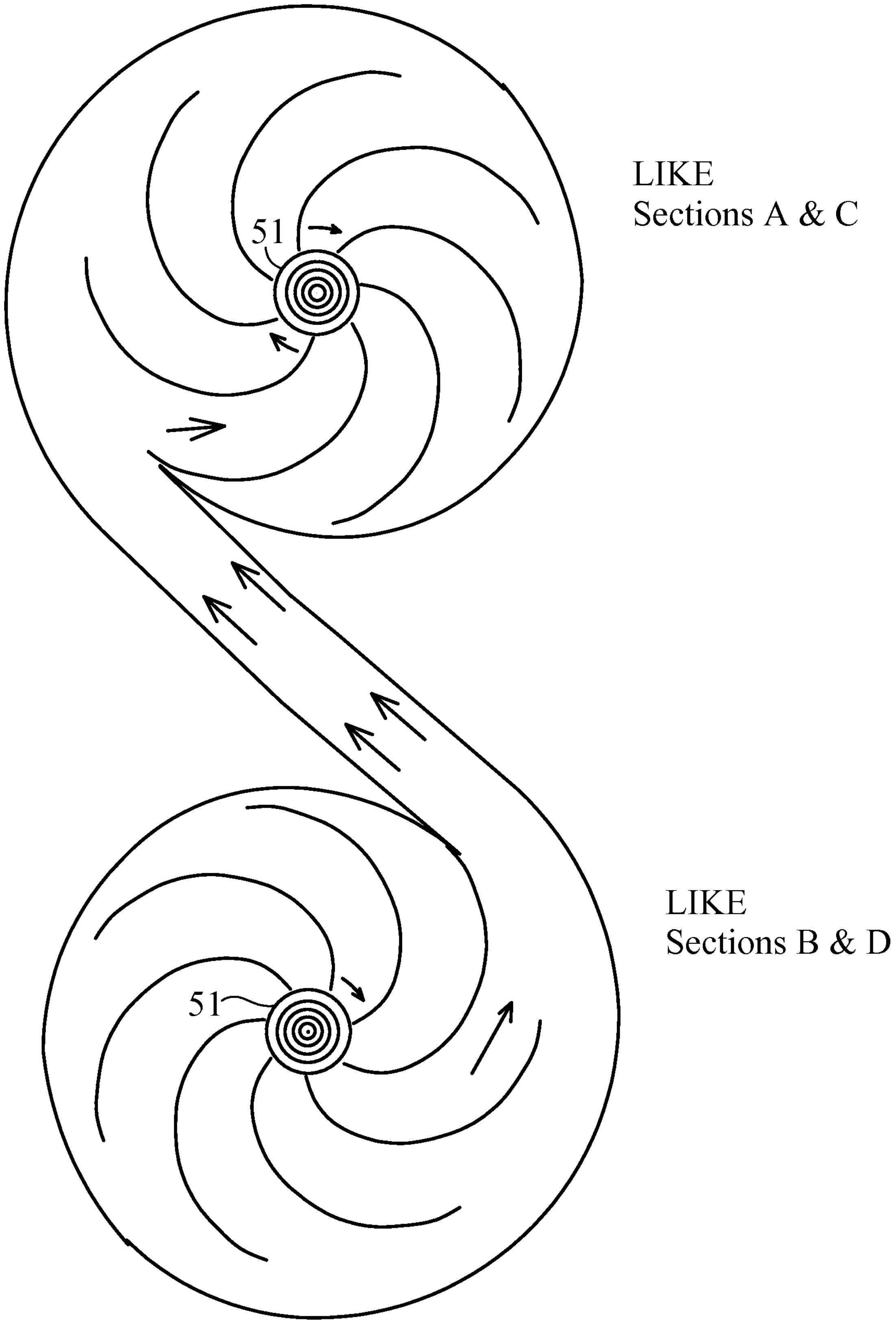

FIGURE 5

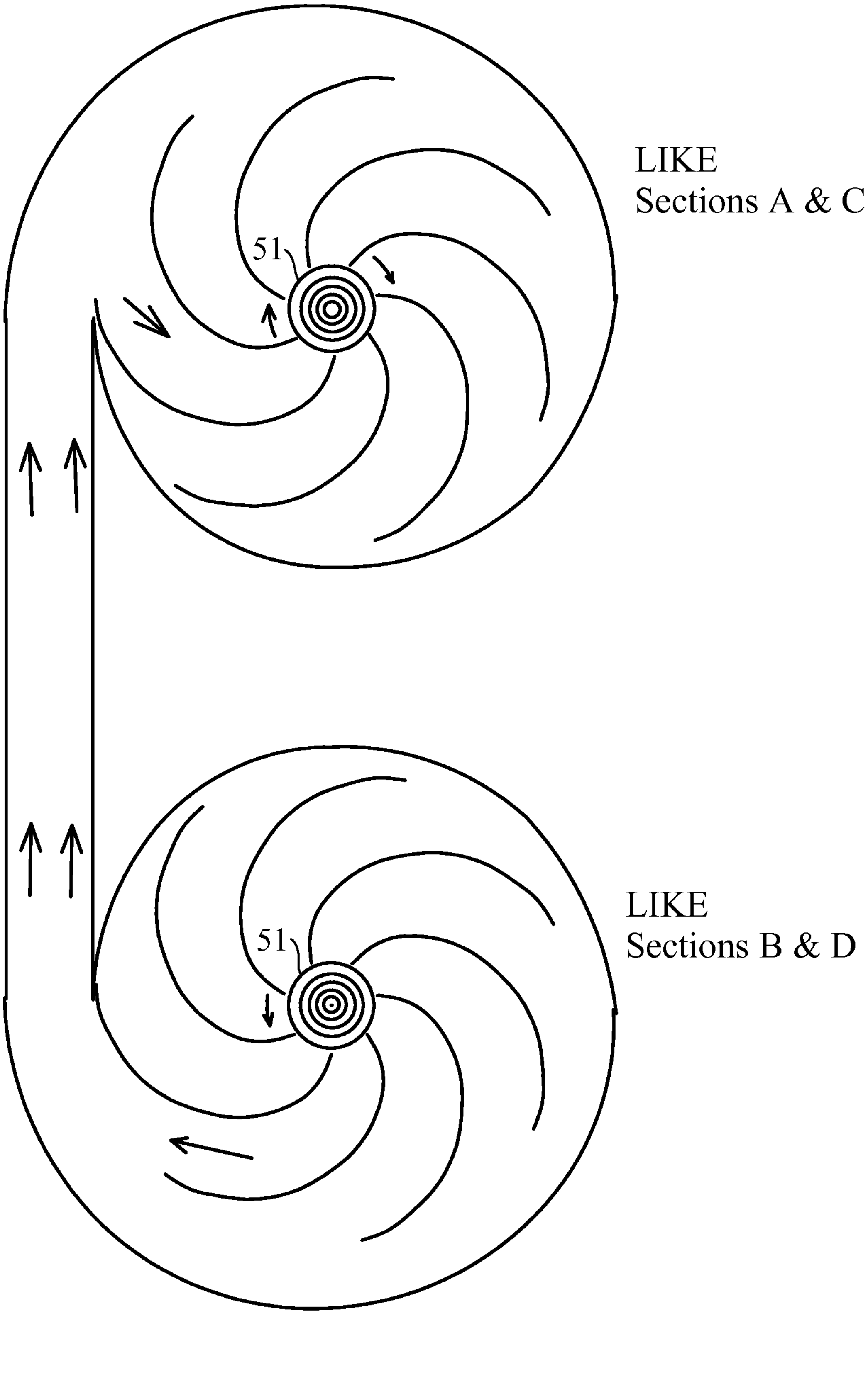

FIGURE 6

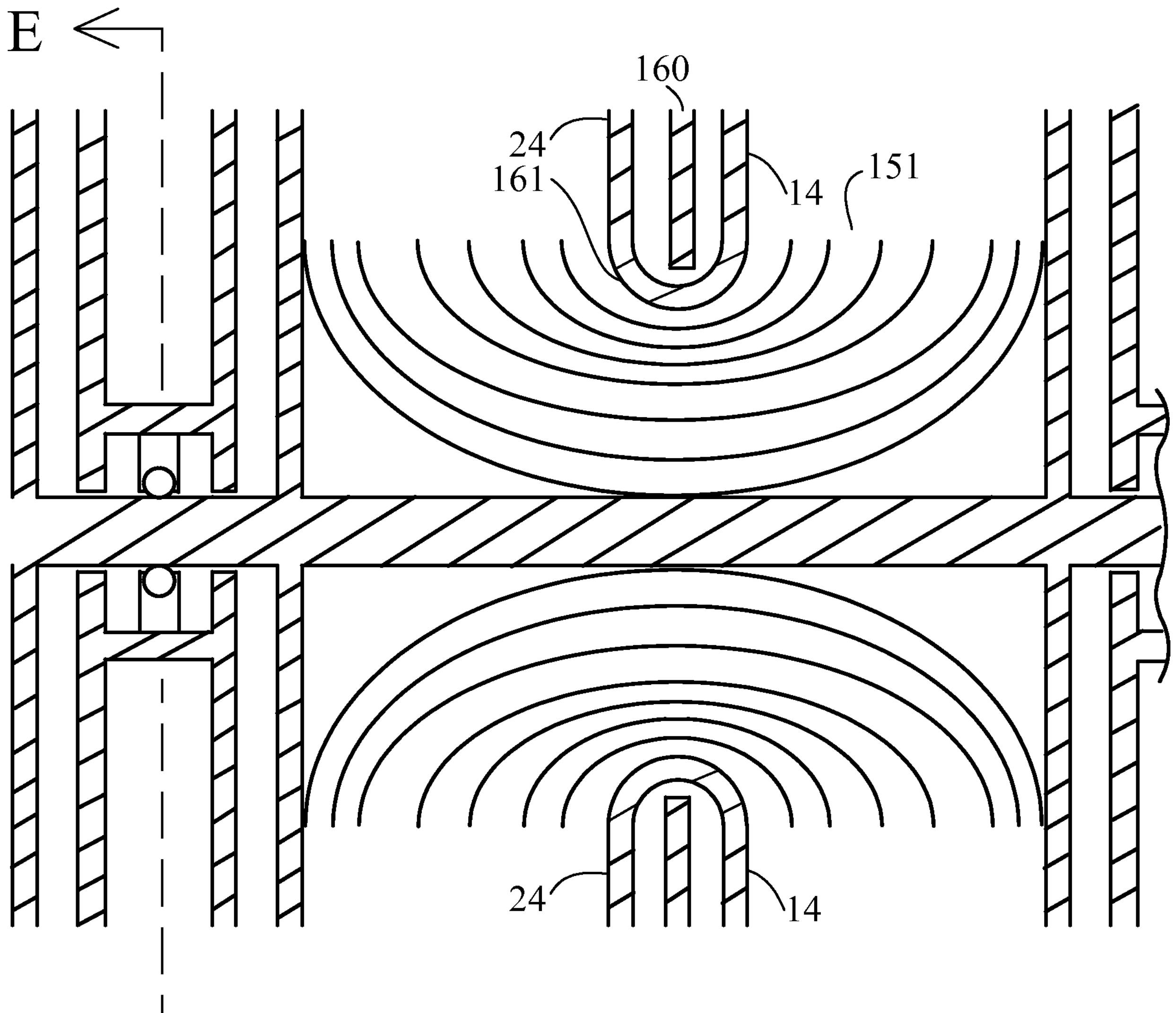

FIGURE 7

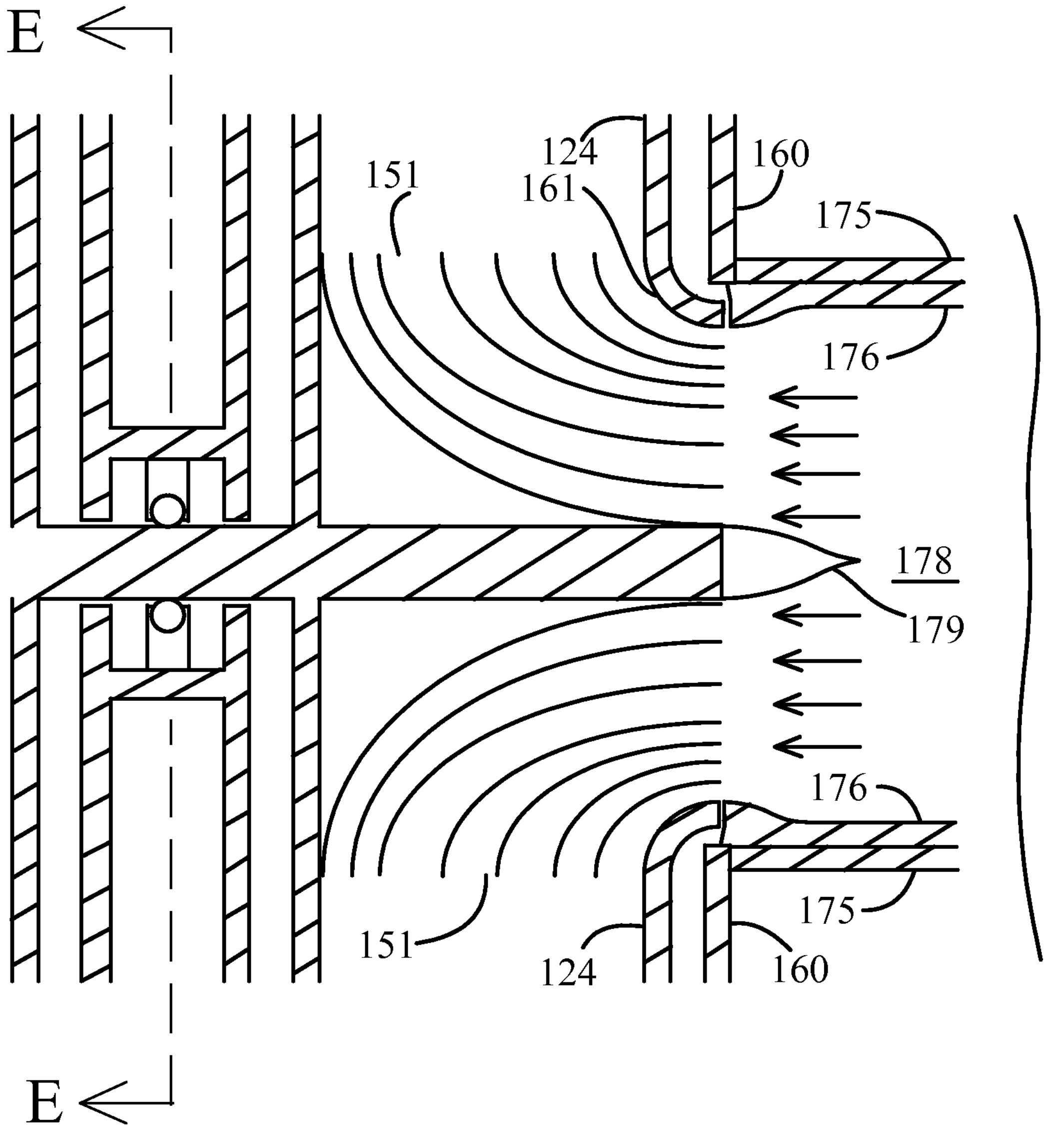

FIGURE 8

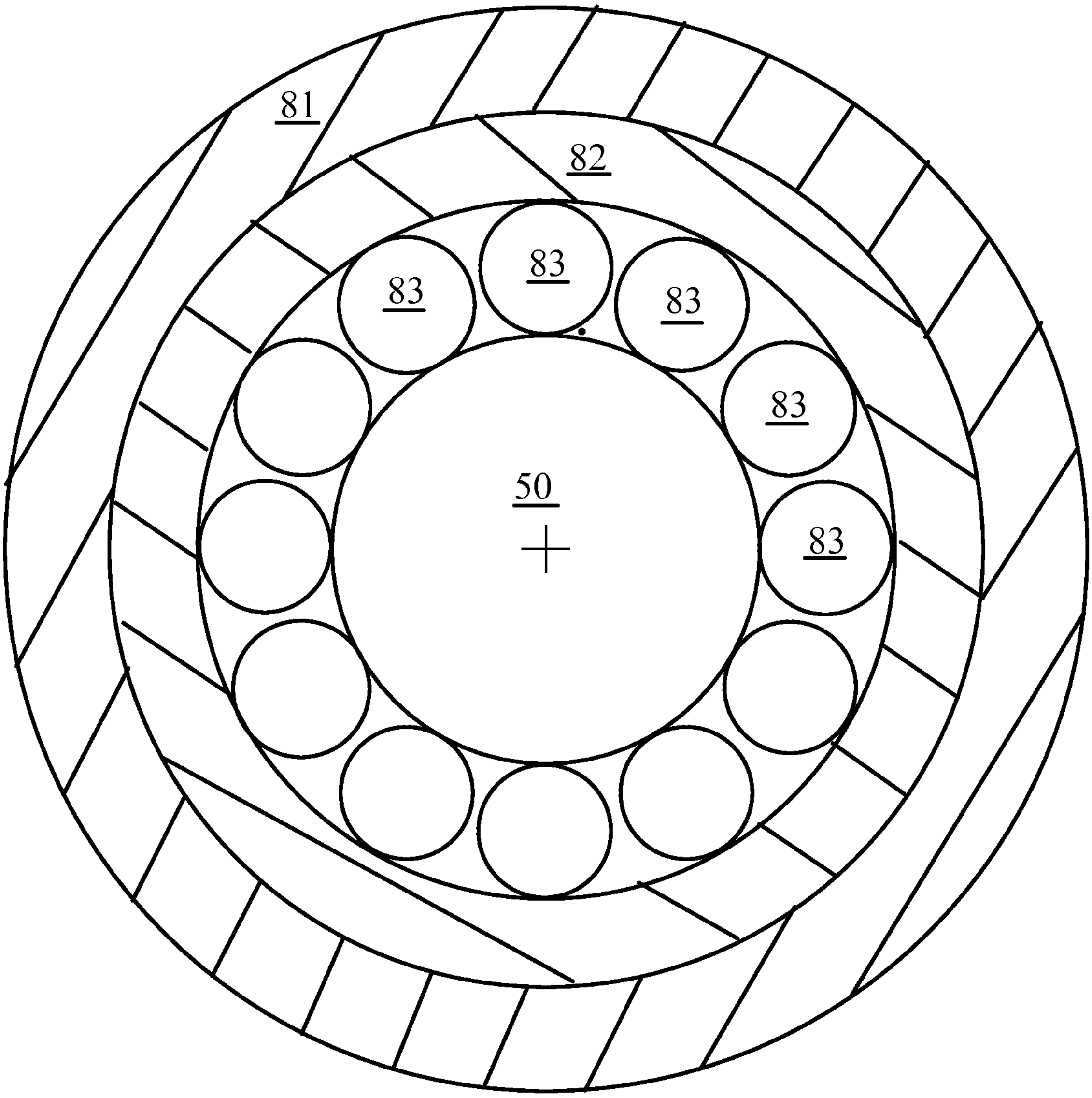

FIGURE 9

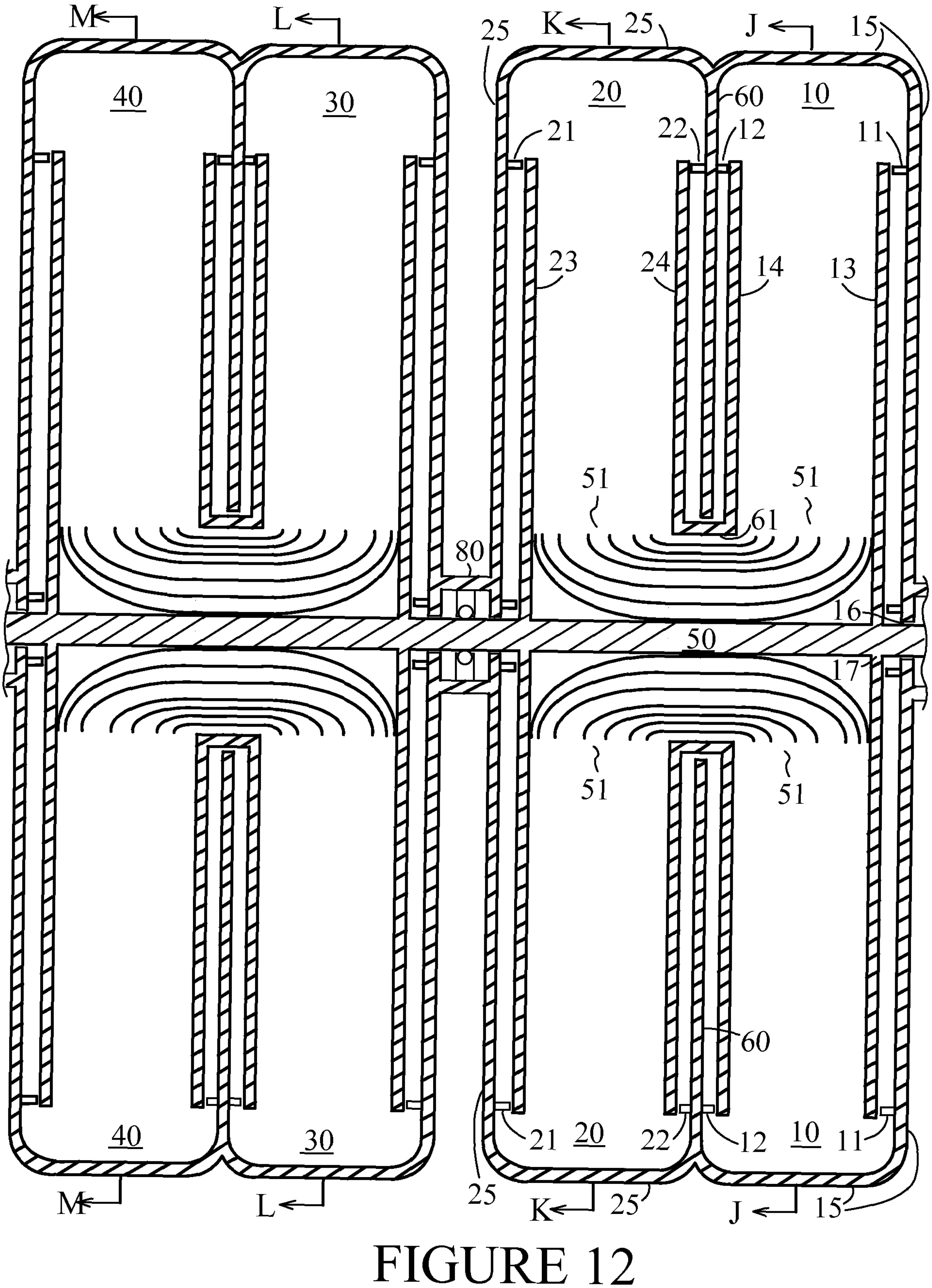
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FIGURE 12

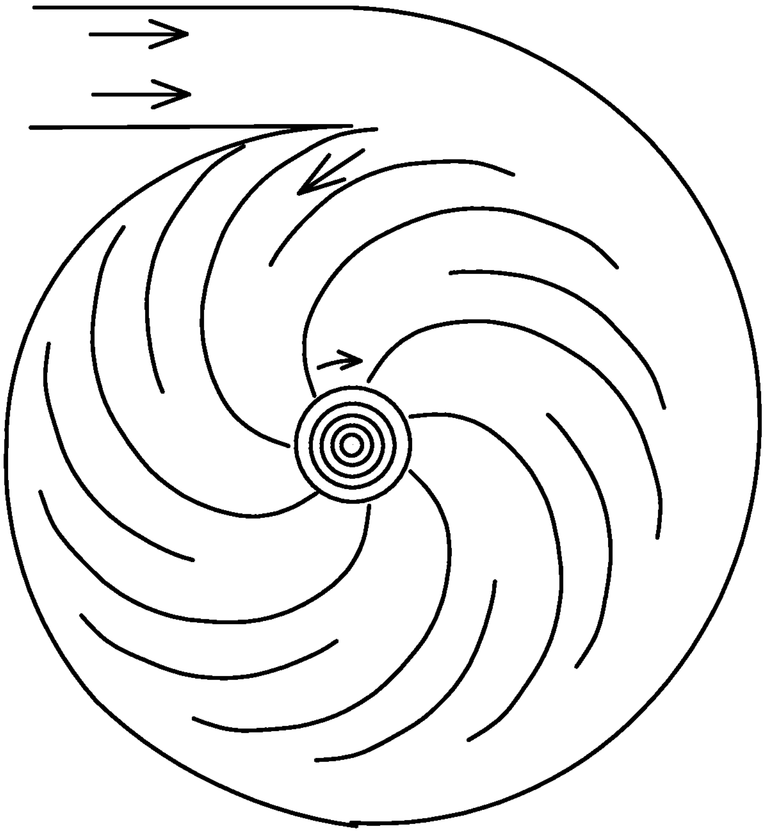

FIGURE 3
Sections A & C

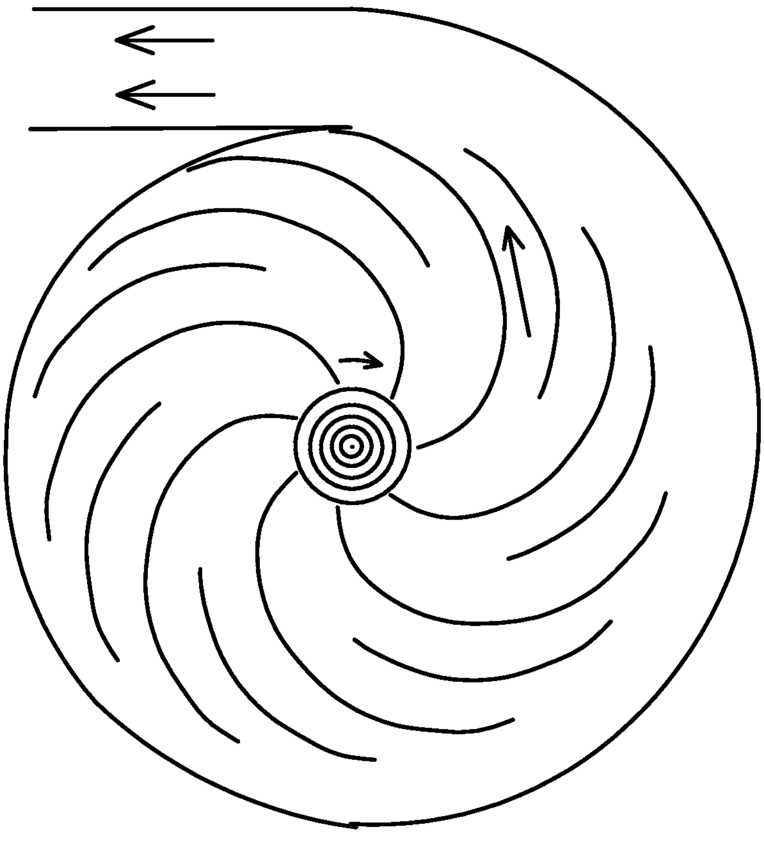

FIGURE 4
Sections B & D

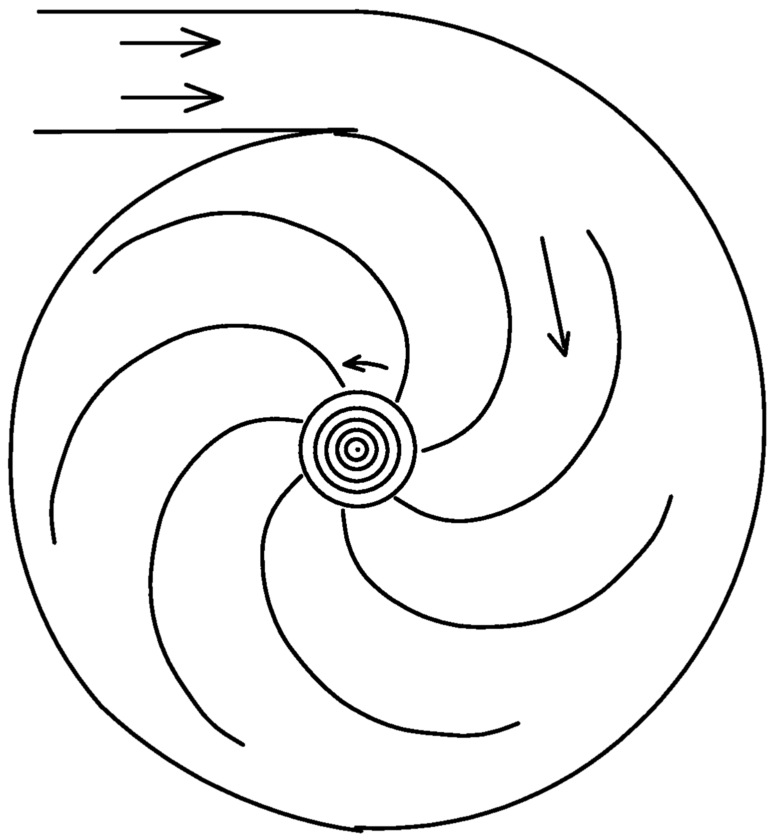

FIGURE 10
Sections J & L

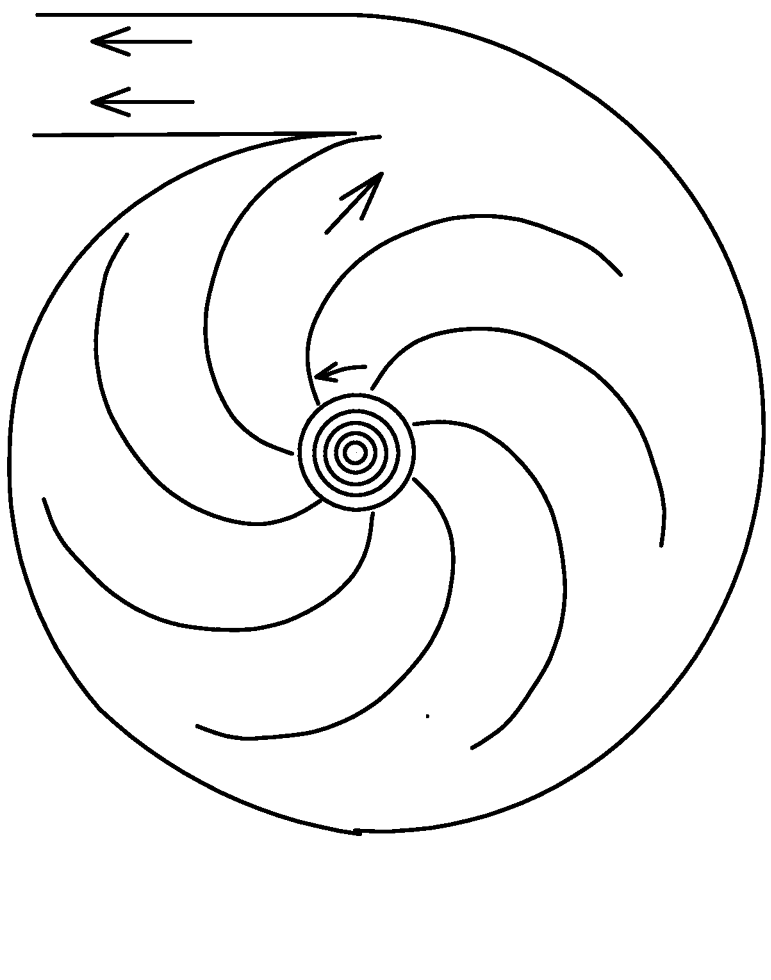

FIGURE 11
Sections K & M

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- WO 8087247 A **[0046]**