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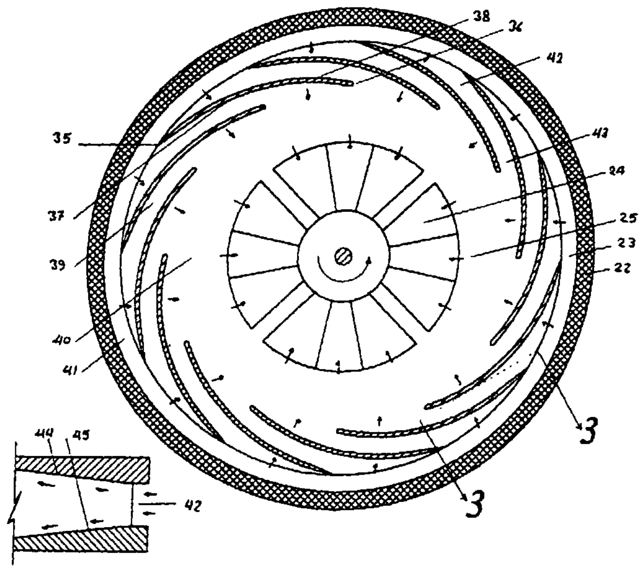

(57) Abstract: The present invention relates to rotary ram fluid pressurizing machines utilizing the phenomenon of ram pressure rise, which occurs when a fluid is rammed into a suitably shaped diffuser moving at a high speed to develop a pressure gradient between two points across a fluid stream. In an exemplary machine, vanes (30) attached to rotary disks (28, 29) form channels (39) which act as diffusers when the disks are rotated to move and pressurize fluid rapidly inwardly or radially outwardly. Various embodiments for pressurizing, pumping or evacuating compressible or incompressible fluids are disclosed.

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ROTARY RAM FLUID PRESSURIZING MACHINE

FIELD OF THE INVENTION

The present invention relates to rotary fluid pressurizing machines that utilize the phenomenon of ram pressure rise resulting from the divergence of a fluid within a suitably shaped diffuser moving at high speed in developing a pressure gradient between two points across a fluid stream, and more particularly to fluid pressurizing machines that can be used with compressible, as well as incompressible fluids, to develop either a positive or a negative pressure gradient.

BACKGROUND OF THE INVENTION

Rotary fluid pressurizing machines are well known devices, used in several fields to develop a pressure gradient between two points across a fluid stream. They are designed for use with compressible fluids, to provide a positive pressure gradient, i.e., compressors, or a negative pressure gradient, i.e., vacuum pumps, or with incompressible fluids, i.e., pumps.

Rotary compressors are machines that increase the pressure of a compressible fluid, i.e., gas, or vapor, or a mixture of gases and vapors. The pressure is increased by reducing the fluid specific volume during passage of the compressible fluid through the compressor. Two main types of rotary compressors are in use, dynamic compressors, i.e., centrifugal flowing, axial flowing, and the combined types, and positive displacement compressors.

Rotary vacuum pumps are machines that reduce the pressure of gas or air in a container. Two main types of rotary vacuum pumps are in use, rotary oil-seal pumps, and dynamic vacuum pumps.

A rotary pump is a machine used to draw an incompressible fluid, i.e., liquid, into itself through an entrance port, and force it out through an exhaust port. It may serve to move fluid, to lift fluid, or to put fluid under pressure. Many types of rotary pumps are in use, e.g., gear pumps, gerotor pumps, and centrifugal pumps, and others.

The ram pressure rise is a well investigated phenomenon by those involved in the design of ramjet engines, and inlet ducts of turbo-jet engines, whether of the subsonic, transonic, or supersonic types. Ram pressure rise occurs when a fluid is rammed into a suitably shaped diffuser moving at a high speed, wherein the fluid is diverged with conversion of the kinetic energy of the fluid relative to the moving diffuser into a rise in the pressure energy of the fluid, referred to as the ram pressure rise. The obtainable ram pressure rise depends on the speed of the moving diffuser, its shape, and the properties of the fluid through which the diffuser is moving.

SUMMARY OF THE INVENTION

In view of the preceding, it is an object of the present invention to provide for rotary ram fluid pressurizing machines, to be used with compressible as well as incompressible fluids, to develop either a positive, or a negative pressure gradient, between two points across the fluid stream, utilizing the phenomenon of ram pressure rise, whereby the amount of energy consumed by the rotary ram fluid pressurizing machine to provide a certain pressure gradient, will be less than that consumed by other conventional types, to provide the same pressure gradient.

It is also an object of the present invention to provide a rotary ram fluid pressurizing machine that is simple in design, and can handle a wide range of fluid mass flow rates, with minimum sealing problems.

It is also an object of the present invention to provide a rotary ram fluid pressurizing machine for applications wherein adjustable control of the volumetric delivery of the pressurized fluid is needed during operation.

It is also an object of the present invention to provide a rotary ram fluid pressurizing machine having an axially movable rotor and two discharge passages, with the provided pressurized fluid being discharged through either one of the two discharge passages, or distributed between both of them with an adjustable variable ratio, according to the position of the axially movable rotor.

Accordingly, the present invention provides rotary ram fluid pressurizing machines, that can be used with compressible fluids, as well as incompressible fluids, to develop either a positive, or a negative pressure gradient between two points across a fluid stream.

In one embodiment, the rotary ram fluid pressurizing machine comprises a stationary casing having an inlet passage for admission of fluid and an exit passage for discharge of the pressurized fluid; a drive shaft supported by an arrangement of bearings, for rotation in a given direction inside the casing and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes a first disk surrounding the drive shaft and lying in a first plane transverse to the rotational axis of the drive shaft, a second disk surrounding the drive shaft and lying in a second plane transverse to the rotational axis of the drive shaft and axially spaced from the first plane, with either both of the disks being secured for rotation with the drive shaft, or only one of them secured for rotation with the drive shaft with the other one having a large open center and a widened rim, and with each of the disks having a relatively outer surface facing its adjacent part of the casing and a relatively inner surface, with the inner surfaces of the two disks defining an annular space in-between, and a plurality of vanes arranged circumferentially within the annular space defined in-between the inner surfaces of the disks. Each of the vanes has a first edge attached to the inner surface of the first disk, a second edge attached to the inner surface of the second disk, a relatively radially outwards leading edge or tip and a relatively radially inward trailing edge or tail, with each vane curved preferably smoothly from its leading edge towards its trailing edge. The average angles of inclination of the successive portions of the vane with respect to a plane comprising the midpoint of the vane and perpendicular to a radial plane including the rotational axis of the rotor and the midpoint of the vane decreases preferably gradually from its leading edge towards its trailing edge, within a range from about +26 to about -48 degrees. Each vane has a concave displacing surface and a convex surface, with the opposing parts of the surfaces of each two adjacent vanes defining a channel between them, with the channel confined by a part of the concave surface of one vane and its opposing part of the convex surface of an adjacent vane. The rest of the concave surface freely communicates with the space relatively radially inwards of the vanes, and the rest of the convex surface freely communicates with the space relatively radially outwards of the vanes. Accordingly, the channel has an inlet communicating with the space relatively radially outwards of the vanes, and an outlet communicating with the space relatively radially inwards of the vanes. The boundaries of the channel are formed of the opposing parts of the surfaces of the two adjacent vanes and of the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes, with the channel diverging from its inlet towards its outlet.

The divergence of the channel is provided by designing the boundaries confining the channel between them so that: 1) the axial width of the channel, and/or 2) the width between the opposing parts of the surfaces of the two adjacent vanes confining the channel between them increase preferably gradually from the inlet of the channel towards its outlet, and hence, the cross-sectional area of the channel increases preferably gradually from its inlet towards its outlet.

The gradual increase in the axial width of the channel is provided by designing the part(s) of the surface(s) of one (or both) of the disks related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes so that it is sloping preferably gradually from the inlet of the channel towards its outlet. The gradual increase in the width between the opposing parts of the surfaces of the two adjacent vanes is provided by designing the vanes with suitable angles of inclination at their different parts, according to the desired rate of divergence of the channel described above.

In operation, the fluid in the space relatively radially outwards of the vanes is rammed into the diverging channels, formed in-between the circumferentially arranged vanes, and is gradually displaced to the space relatively radially inwards of the vanes, while being diverged, resulting into a rise in the static pressure energy of the fluid within the diverging channels.

The fluid is fed to the space relatively radially outwards of the vanes through one or more than one inlet port(s) in the casing, and the pressurized fluid is discharged through one or more than one opening(s) in either one or both of the disks, within the disk(s) portion confined between the vanes and the drive shaft, and communicating with the exit passage in the casing.

The volumetric capacity of the rotary ram fluid pressurizing machine depends on the number of diverging channels confined between the vanes, their dimensions, and the speed of the vanes leading edges. In the present embodiment, to increase the volumetric capacity without marked increase in the height of the vanes, to avoid the formation of excessive centrifugal and bending stresses, one or more than one further, circumferentially arranged, vane level in axially stacked relation is used, with intervening disk(s) between each two adjacent levels, with the attached edges of each of the vanes being attached to their related surfaces of the disks. The design and operation of the vanes of the further level(s) are quite similar to those of the single leveled embodiment, discussed herein before. Opening(s) in the intervening disk(s) portion confined between the circumferentially arranged vanes and the drive shaft may be provided, to functionally communicate the formed sub-spaces inside the rotor. One or more than one of the disks may be fixed to the casing, with the vane edges related to the fixed disk(s) being free, i.e., not attached to their related surface(s) of the disk(s). The fixed disk(s) may provide further support to the shaft through suitable an arrangement of bearings in-between.

The speed of the vane leading edges cannot be increased above the speed of sound without the formation of shock waves in case of compressible fluids. Similarly, the speed of the vane leading edges cannot be increased above the critical velocity without creating turbulence in the flow in case of incompressible fluids. Accordingly, the obtainable ram pressure rise from this embodiment will have a certain upper limit.

To further increase the obtainable static pressure rise, further vanes, arranged in one or more concentric sets, inward of the periphery, may be used, with the design and operation of the further vanes being quite similar to those of the single stage embodiment discussed herein before, so that in operation, the fluid in the space relatively radially outwards of each of the vane sets is rammed into the inlets of the diverging channels formed between the vanes, and is gradually displaced to the space relatively radially inwards of the set of vanes while being diverged. The overall ram pressure rise in the space relatively radially inwards of the innermost set of vanes, will equal the multiplication of the ram pressure rises obtained from the successive concentric sets of vanes.

In another embodiment, the rotary ram fluid pressurizing machine comprises a stationary casing having an inlet passage for admission of fluid and an exit passage for discharge of the pressurized fluid; a drive shaft supported for rotation in a given direction inside the casing by an arrangement of bearings, and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes a first disk surrounding the drive shaft and lying in a first plane transverse to the rotational axis of the drive shaft, a second disk surrounding the drive shaft and lying in a second plane transverse to the rotational axis of the drive shaft and axially spaced from the first plane, with either both of the disks being secured for rotation with the drive shaft, or only one of them secured for rotation with the drive shaft with the other one having a large open center and a widened rim, and with each of the disks having a relatively outer surface facing its adjacent part of the casing and a relatively inner surface, with the inner surfaces of the two disks defining an annular space in-between, and a plurality of vanes arranged circumferentially within the annular space defined in-between the inner surfaces of the disks. Each of the vanes has a first edge attached to the inner surface of the first disk, a second edge attached to the inner surface of the second disk, a relatively radially inward leading edge or tip, and a relatively radially outward trailing edge or tail, with each vane curved preferably smoothly from its leading edge towards its trailing edge. The average angles of inclination of the successive portions of the vane with respect to a plane comprising the midpoint of the vane and perpendicular to a radial plane including the rotational axis of the rotor and the midpoint of the vane decreases preferably gradually from its leading edge towards its trailing edge, within a range from about +56 to about -20 degrees. Each vane has a convex displacing surface and a concave surface, with the opposing parts of the surfaces of each two adjacent vanes defining a channel between them, with the channel confined by a part of the concave surface of one vane and its opposing part of the convex surface of an adjacent vane. The rest of the concave surface freely communicates with the space relatively radially inwards of the vanes, and the rest of the convex surface freely communicates with the space relatively radially outwards of the vanes. Accordingly, The channel has an inlet communicating with the space relatively radially inwards of the vanes, and an outlet communicating with the space relatively radially outwards of the vanes. The boundaries of the channel are formed of the opposing parts of the surfaces of the two adjacent vanes and of the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes, with the channel diverging from its inlet towards its outlet.

The divergence of the channel is provided by designing the boundaries confining the channel between them so that the axial width of the channel and/or the width between the opposing parts of the surfaces of the two adjacent vanes confining the channel between them increase preferably gradually from the inlet of the channel towards its outlet, and hence, the cross-sectional area of the channel increases preferably gradually from its inlet towards its outlet.

The gradual increase in the axial width of the channel is provided by designing the part(s) of the surface(s) of one (or both) of the disks related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes so that it is sloping preferably gradually from the inlet of the channel towards its outlet. The gradual increase in the width between the opposing parts of the surfaces of the two adjacent vanes is provided by designing the vanes with suitable angles of inclination at their different parts, according to the desired rate of divergence of the channel.

In operation, the fluid in the space relatively radially inward of the vanes is rammed into the diverging channels formed in-between the circumferentially arranged vanes, and is gradually displaced to the space relatively radially outwards of the vanes, while being diverged, resulting in a rise in the static pressure energy of the fluid within the diverging channels.

The fluid is fed to the space relatively radially inwards of the vanes through one, or more than one, inlet port in the casing, communicating with the space, through one, or more than one, opening in either one or both of the disks, within the portion of the disk confined between the vanes and the drive shaft. The pressurized fluid is discharged from the space relatively radially outwards of the vanes through one or more than one exit passage(s) in the casing.

As the volumetric capacity of the rotary ram fluid pressurizing machine depends on the number of diverging channels confined between the vanes, their dimensions, and the speed of the vanes leading edges, so, to increase the volumetric capacity in the present invention, without marked increase in the height of the vanes, to avoid the formation of excessive centrifugal and bending stresses, one or more than one further, circumferentially arranged, vane level in axially stacked relation, is used, with intervening disk(s) between each two adjacent levels, with the attached edges of each of the vanes being attached to their related surfaces of the disks. The design and operation of the vanes of the further level(s) are quite similar to those of the single leveled embodiment, discussed herein before.

The intervening disk(s) may be provided with opening(s) in the portion of the disk(s) confined between the circumferentially arranged vane levels and the drive shaft to equalize the pressure level at the inlets of the diverging channels confined between the vanes.

The speed of the vane trailing edges cannot be increased above the speed of sound without the formation of shock waves in case of compressible fluids. Similarly, the speed of the vane trailing edges cannot be increased above the critical velocity without creating turbulence in the flow in case of incompressible fluids. Accordingly, the obtainable ram pressure rise from this embodiment will have a certain upper limit.

To further increase the obtainable static pressure rise, further vanes, arranged in one or more concentric sets, inward of the periphery, may be used, with the design and operation of the further vanes being quite similar to those of the single stage embodiment discussed herein before, so that in operation, the fluid in the space relatively radially inward of each of the vane sets is rammed into the inlets of the diverging channels formed between the vanes, and is gradually displaced to the space relatively radially outwards of the set of vanes while being diverged. The overall ram pressure rise in the space relatively radially outwards of the outermost set of vanes, will equal the multiplication of the ram pressure rises obtained from the successive concentric sets of vanes.

Any of the previous rotary ram fluid pressurizing machine embodiments discussed herein before, can be used as a vacuum pump, to decrease the pressure of a fluid inside a container, by freely communicating the exit passage of the rotary ram fluid pressurizing machine to the surrounding atmosphere, and communicating its inlet passage(s) with the container. In operation, the fluid inside the container is rammed out of it, through the diverging channels confined between the vanes of the rotor assembly of the rotary ram fluid pressurizing machine, and is discharged to the surrounding atmosphere, and thus, decreases the pressure of the fluid inside the container.

The present invention also provides a rotary ram fluid pressurizing machine with adjustable control of volumetric capacity, for the applications in which the mass flow rates of the provided pressurized fluid is changeable during operation.

In one embodiment, the variable capacity rotary ram fluid pressurizing machine comprises a stationary casing, having an inlet passage for admission of the fluid and an exit passage for discharge of the pressurized fluid; a first shaft supported for rotation in a give direction in the casing by an arrangement of bearings, and extending to a drive receiving end located outside the casing; a second shaft concentric with the first shaft, and supported by an arrangement of bearings for rotation in the casing, with the rotational support of one of the two shafts designed to allow for axial movement of the shaft, while the rotational support of the other shaft is designed so that the shaft is axially fixed; and a rotor assembly located inside the casing. The rotor assembly includes a first disk surrounding the first shaft and lying in a first plane transverse to the rotational axis of the first shaft, a second disk surrounding the second shaft and lying in a second plane transverse to the rotational axis of the second shaft and axially spaced from the first plane, with the first disk secured for rotation with the first shaft, and with the second disk secured for rotation with the second shaft, with each of the disks having a relatively outer surface facing its adjacent part of the casing, and a relatively inner surface, with inner surfaces of the two disks defining an annular space in-between, and a plurality of vanes arranged circumferentially within the annular space defined in-between the inner surfaces of the disks. Each of the vanes has a first edge attached to the inner surface of one of the disks, a second edge forming male end in fluid tight communication with a female groove in the inner surface of the other disk, a relatively radially outward leading edge or tip, and a relatively radially inward trailing edge or tail, with each vane curved preferably smoothly from its leading edge towards its trailing edge. The average angles of inclination of the successive portions of the vane with respect to a plane comprising the midpoint of the vane and perpendicular to a radial plane including the rotational axis of the rotor and the midpoint of the vane decreases preferably gradually from its leading edge towards its trailing edge, within a range from about +26 to about -48 degrees. Each vane has a concave displacing surface and a convex surface, with the opposing parts of the surfaces of each two adjacent vanes defining a channel between them, with the channel confined by a part of the concave surface of one vane and its opposing part of the convex surface of an adjacent vane. The rest of the concave surface freely communicates with the space relatively radially inwards of the vanes, and the rest of the convex surface freely communicates with the space relatively radially outwards of the vanes. Accordingly, the channel has an inlet communicating with the space relatively radially outwards of the vanes, and an outlet communicating with the space relatively radially inwards of the vanes. The boundaries of the channel are formed of the opposing parts of the surfaces of the two adjacent vanes and of the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes, with the channel diverging from its inlet towards its outlet.

The divergence of the channel is provided by designing the boundaries confining the channel between them so that the axial width of the channel and/or the width between the opposing parts of the surfaces of the two adjacent vanes confining the channel between them increase preferably gradually from the inlet of the channel towards its outlet, and hence, the cross-sectional area of said channel increases preferably gradually from its inlet towards its outlet.

The gradual increase in the axial width of the channel is provided by designing the part(s) of the surface(s) of one (or both) of the disks related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes so that it is sloping preferably gradually from the inlet of the channel towards its outlet. The gradual increase in the width between the opposing parts of the surfaces of the two adjacent vanes is provided by designing the vanes with suitable angles of inclination at their different parts, according to the desired rate of divergence of the channel.

The design and operation of the variable capacity rotary ram fluid pressurizing machine of this embodiment is quite similar to those of the rotary ram fluid pressurizing machine embodiments described herein before, wherein the fluid is rammed in an inward direction from the space relatively radially outwards of the vanes to the space relatively radially inward of the vanes.

In operation, the volumetric delivery is regulated by variations in the axial width of the diverging channels confined between the vanes and the inner surfaces of the disks. This is achieved by axially moving the axially movable shaft, with the axial movement of the shaft being transmitted to the disk mounted on it, which results in changing the axial width between the inner surfaces of the two disks, and hence, the axial width of the diverging channels.

The axial movement of the axially movable shaft can be provided by mechanical, electro-mechanical, electrical, hydraulic, or pneumatic means. Such means are well known to those of ordinary skill in the art.

As mentioned herein before, to increase the obtainable static pressure rise, further vanes, arranged in one, or more concentric sets, inward of the periphery, may be used, with each of the further vanes having an edge forming male end in fluid tight communication with a further female groove in the inner surface of one of the disks.

The design and operation of the vanes of the further set(s) are quite similar to those of the single stage variable capacity rotary ram fluid pressurizing machine described herein before, wherein on operation, the fluid in the space relatively radially outwards of each of the vane sets is rammed into the inlets of the diverging channels formed between the vanes, and is gradually displaced to the space relatively radially inwards of the set of vanes while being diverged. The overall ram pressure rise in the space relatively radially inwards of the innermost set of vanes, will equal the multiplication of the ram pressure rises obtained from the successive concentric sets of vanes.

In another embodiment, the variable capacity rotary ram fluid pressurizing machine comprises a stationary casing, having an inlet port(s) for admission of the fluid and an exit port(s) for discharge of the pressurized fluid; a first shaft supported for rotation in a given direction in the casing, by an arrangement of bearings, and extending to a drive receiving end located outside the casing; a second shaft concentric with the first shaft, and supported for rotation in the casing by an arrangement of bearings, with the rotational support of one of the two shafts designed to allow for axial movement of the shaft, while the rotational support of the other shaft is designed so that the shaft is axially fixed; and a rotor assembly located inside the casing. The rotor assembly includes a first disk surrounding the first shaft and lying in a first plane transverse to the rotational axis of the first shaft, a second disk surrounding the second shaft and lying in a second plane transverse to the rotational axis of the second shaft and axially spaced from the first plane, with the first disk secured for rotation with the first shaft, and with the second disk secured for rotation with the second shaft, with each of the disks having a relatively outer surface facing its adjacent part of the casing, and a relatively inner surface, with inner surfaces of the two disks defining an annular space in-between, and a plurality of vanes arranged circumferentially within the annular space defined in-between the inner surfaces of the disks. Each of the vanes has a first edge attached to the inner surface of one of the disks, a second edge forming male end in fluid tight communication with a female groove in the inner surface of the other disk, a relatively radially inward leading edge or tip, and a relatively radially outward trailing edge or tail, with each vane curved preferably smoothly from its leading edge towards its trailing edge. The average angles of inclination of the successive portions of the vane with respect to a plane comprising the midpoint of the vane and perpendicular to a radial plane including the rotational axis of the rotor and the midpoint of the vane decreases preferably gradually from its leading edge towards its trailing edge, within a range from about +56 to about -20 degrees. Each vane has a convex displacing surface and a concave surface, with the opposing parts of the surfaces of each two adjacent vanes defining a channel between them, with the channel confined by a part of the concave surface of one vane and its opposing part of the convex surface of an adjacent vane. The rest of the concave surface freely communicates with the space relatively radially inwards of the vanes, and the rest of the convex surface freely communicates with the space relatively radially outwards of the vanes. Accordingly, the channel has an inlet communicating with the space relatively radially inwards of the vanes, and an outlet communicating with the space relatively radially outwards of the vanes. The boundaries of the channel are formed of the opposing parts of the surfaces of the two adjacent vanes and of the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes, with the channel diverging from its inlet towards its outlet.

The divergence of the channel is provided by designing the boundaries confining the channel between them so that the axial width of the channel and/or the width between the opposing parts of the surfaces of the two adjacent vanes confining the channel between them increase preferably gradually from the inlet of the channel towards its outlet, and hence, the cross-sectional area of the channel increases preferably gradually from its inlet towards its outlet.

The gradual increase in the axial width of the channel is provided by designing the part(s) of the surface(s) of one (or both) of the disks related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes so that it is sloping preferably gradually from the inlet of the channel towards its outlet. The gradual increase in the width between the opposing parts of the surfaces of the two adjacent vanes is provided by designing the vanes with suitable angles of inclination at their different parts, according to the desired rate of divergence of the channel.

The design and operation of the variable capacity rotary ram fluid pressurizing machine of this embodiment is quite similar to those of the rotary ram fluid pressurizing machine embodiments described herein before, wherein the fluid is rammed in an outward direction from the space relatively radially inward of the vanes to the space relatively radially outwards of the vanes.

In operation, the volumetric delivery is regulated by variations in the axial width of the diverging channels confined between the vanes and the inner surfaces of the disks. This is achieved by axially moving the axially movable shaft, with the axial movement of the shaft being transmitted to the disk mounted on it, which results in changing the axial width between the inner surfaces of the two disks, and hence, the axial width of the diverging channels.

The axial movement of the axially movable shaft can be provided by mechanical, electro-mechanical, electrical, hydraulic, or pneumatic means. Such means are well known to those of ordinary skill in the art.

As mentioned herein before, to increase the obtainable static pressure rise, further vanes, arranged in one, or more concentric sets, inward of the periphery, may be used, with each of the further vanes having an edge forming male end in fluid tight communication with a further female groove in the inner surface of one of the disks.

The design and operation of the vanes of the further set(s) are quite similar to those of the single stage variable capacity rotary ram fluid pressurizing machine described herein before, wherein on operation, the fluid in the space relatively radially inward of each of the vane sets is rammed into the inlets of the diverging channels formed between the vanes, and is gradually displaced to the space relatively radially outwards of the set of vanes while being diverged. The overall ram pressure rise in the space relatively radially outwards of the outermost set of vanes, will equal the multiplication of the ram pressure rises obtained from the successive concentric sets of vanes.

The rotary ram fluid pressurizing machine provided in the present invention can be used in the applications wherein two discharge passages are used, with the provided pressurized fluid being discharged through either one of the two discharge passages, or distributed between both of them with an adjustable variable ratio, as needed during operation.

In one embodiment, the rotary ram fluid pressurizing machine comprises a stationary casing having an inlet passage(s) for admission of the fluid and two exit passages in axially stacked relation, and separated by an intermediate disk-shaped septum, with each exit passage having a separate exit port(s); an axially movable shaft, supported for rotation in a given direction in the casing, by bearing or concentric shaft means, allowing for its axial movement, with the shaft extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes a first disk surrounding the shaft and lying in a first plane transverse to the rotational axis of the shaft, a second disk surrounding the shaft and lying in a second plane transverse to the rotational axis of the shaft and axially spaced from the first plane, with either both of the disks being secured for rotation with the shaft, or only one of them secured for rotation with the shaft with the other one having a large open center and a widened rim, and with each of the disks having a relatively outer surface facing its adjacent part of the casing and a relatively inner surface, with the inner surfaces of the two disks defining an annular space in-between, and a plurality of vanes arranged circumferentially within the annular space defined in-between the inner surfaces of the disks. Each of the vanes has a first edge attached to the inner surface of the first disk, a second edge attached to the inner surface of the second disk, a relatively radially inward leading edge or tip and a relatively radially outward trailing edge or tail, with each vane curved preferably smoothly from its leading edge towards its trailing edge. The average angles of inclination of the successive portions of the vane with respect to a plane comprising the midpoint of the vane and perpendicular to a radial plane including the rotational axis of the rotor and the midpoint of the vane decreases preferably gradually from its leading edge towards its trailing edge, within a range from about +56 to about -20 degrees. Each vane has a convex displacing surface and a concave surface, with the opposing parts of the surfaces of each two adjacent vanes defining a channel between them, with the channel confined by a part of the concave surface of one vane and its opposing part of the convex surface of an adjacent vane. The rest of the concave surface freely communicates with the space relatively radially inwards of the vanes, and the rest of the convex surface freely communicates with the space relatively radially outwards of the vanes. Accordingly, the channel has an inlet communicating with the space relatively radially inwards of the vanes, and an outlet communicating with the space relatively radially outwards of the vanes. The boundaries of the channel are formed of the opposing parts of the surfaces of the two adjacent vanes and of the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes, with the channel diverging from its inlet towards its outlet.

The divergence of the channel is provided by designing the boundaries confining the channel between them so that the axial width of the channel and/or the width between the opposing parts of the surfaces of the two adjacent vanes confining the channel between them increase preferably gradually from the inlet of the channel towards its outlet, and hence, the cross-sectional area of the channel increases preferably gradually from its inlet towards its outlet.

The gradual increase in the axial width of the channel is provided by designing the part(s) of the surface(s) of one (or both) of the disks related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes so that it is sloping preferably gradually from the inlet of the channel towards its outlet. The gradual increase in the width between the opposing parts of the surfaces of the two adjacent vanes is provided by designing the vanes with suitable angles of inclination at their different parts, according to the desired rate of divergence of the channel.

The design and operation of the rotor assembly of this embodiment is quite similar to those of the rotary ram fluid pressurizing machine embodiments described herein before, wherein the fluid is rammed in an outward direction from the space relatively radially inward of the vanes to the space relatively radially outwards of the vanes.

In operation, the axial movement of the axially movable shaft is transmitted to the rotor assembly mounted on it, which results in changing the axial position of the peripheral part of the rotor assembly, through which the pressurized fluid is discharged, relative to the axially stacked exit passages, so that the pressurized fluid may be discharged either completely through the first exit passage, or completely through the second exit passage, or distributed between them with an adjustable ratio, as needed.

In the present embodiment, to increase the volumetric capacity without marked increase in the height of the vanes, to avoid the formation of excessive centrifugal and bending stresses, one or more than one further, circumferentially arranged, vane level in axially stacked relation is used, with intervening disk(s) between each two adjacent levels, with the attached edges of each of the vanes being attached to their related surfaces of the disks. The design and operation of the vanes of the further level(s) are quite similar to those of the single leveled embodiment, discussed herein before. The intervening disk(s) are provided with opening(s) in the disk(s) portion confined between the circumferentially arranged vane levels and the axially movable shaft to equalize the pressure level at the inlets of the diverging channels confined between the vanes.

The speed of the vane trailing edges cannot be increased above the speed of sound without the formation of shock waves in case of compressible fluids. Similarly, the speed of the vane trailing edges cannot be increased above the critical velocity without turbulence in the flow in case of incompressible fluids. Accordingly, the obtainable ram pressure rise from this embodiment will have a certain upper limit.

To further increase the obtainable static pressure rise, further vanes, arranged in one or more concentric sets, inward of the periphery, may be used, with the design and operation of the further vanes being quite similar to those of the single stage embodiment discussed herein before, wherein on operation, the fluid in the space relatively radially inward of each of the vane sets is rammed into the inlets of the diverging channels formed between the vanes, and is gradually displaced to the space relatively outwards of the set of vanes while being diverged. The overall ram pressure rise in the exit passage(s) will equal the multiplication of the ram pressure rises obtained from the successive concentric sets of vanes.

The axial movement of the axially movable shaft can be provided by mechanical, electro-mechanical, electrical, hydraulic, or pneumatic means. Such means are well known to those of ordinary skill in the art.

The present invention also provides a rotary ram fluid pressurizing machines, that is relatively simpler in design, for applications where design simplicity is of more concern than providing optimum efficiency during operation. Accordingly, in one embodiment, the rotary ram fluid pressurizing machine comprises a stationary casing having an inlet passage for admission of fluid and an exit passage for discharge of the pressurized fluid; a drive shaft supported for rotation in a given direction inside the casing by an arrangement of bearings, and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes one disk surrounding the drive shaft and lying in a plane transverse to the rotational axis of the drive shaft, and secured for rotation with the drive shaft, and a plurality of vanes arranged circumferentially within the annular space defined in-between one of the surfaces of the disk and the opposing part of the inner surface of the casing. Each of the vanes has a first edge attached to its related surface of the disk, a second free edge, a relatively radially outwards leading edge or tip and a relatively radially inward trailing edge or tail, with each vane curved preferably smoothly from its leading edge towards its trailing edge. The average angles of inclination of the successive portions of the vane with respect to a plane comprising the midpoint of the vane and perpendicular to a radial plane including the rotational axis of the rotor and the midpoint of the vane decreases preferably gradually from its leading edge towards its trailing edge, within a range from about +26 to about -48 degrees. Each vane has a concave displacing surface and a convex surface with the opposing parts of the surfaces of each two adjacent vanes defining a channel between them, with the channel confined by a part of the concave surface of one vane and the opposing part of the convex surface of an adjacent vane. The rest of the concave surface freely communicates with the space relatively radially inwards of the vanes, and the rest of the convex surface freely communicates with the space relatively radially outwards of the vanes. Accordingly, the channel has an inlet communicating with the space relatively radially outwards of the vanes, and an outlet communicating with the space relatively radially inwards of the vanes. The boundaries of the channel are formed of the opposing parts of the surfaces of the two adjacent vanes and of the opposing parts of the surfaces of the disk and the casing related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes, with the channel diverging from its inlet towards its outlet. It should be observed that the part of the surface of the casing sharing in the formation of the boundaries of the channel is continuously changing during operation.

The divergence of the channel is provided by designing the boundaries confining said channel between them so that: 1) the axial width of the channel, and/or 2) the width between the opposing parts of the surfaces of the two adjacent vanes confining the channel between them increases preferably gradually from the inlet of the channel towards the outlet of the channel. Thereby, the cross-sectional area of the channel gradually increases from its inlet towards its outlet.

The gradual increase in the axial width of the channel is provided by designing the part of the surface of the disk related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes so that it is sloping preferably gradually from the inlet of the channel towards its outlet. The gradual increase in the width between the opposing parts of the surfaces of the two adjacent vanes is provided by designing the vanes with suitable angles of inclination at their different parts, according to the desired rate of divergence of the channels described above.

In operation, the fluid in the space relatively radially outwards of the vanes is rammed into the diverging channels formed in-between the circumferentially arranged vanes, and is gradually displaced to the space relatively radially inwards of the vanes while being diverged. This results in a rise in the static pressure energy of the fluid within the diverging channels.

The volumetric capacity of a rotary ram fluid pressurizing machine depends on the number of diverging channels confined between the vanes, their dimensions, and the speed of the vanes' leading edges. To increase the volumetric capacity without marked increase in the height of the vanes in the present embodiment, to avoid the formation of excessive centrifugal and bending stresses, a further level of vanes arranged circumferentially within the annular space defined in-between the other surface of the disk and its opposing part of the inner surface of the casing may optionally be used, with each of the vanes having an edge attached to the related surface of the disk, and a free edge. The design and operation of the vanes of the further level are quite similar to those of the single leveled embodiment, discussed before. Opening(s) in the disk(s) portion confined between the circumferentially arranged vanes and the drive shaft may be provided, to provide functional communication between the sub-spaces formed inside the rotor.

The speed of the vane leading edges cannot be increased above the speed of sound without the formation of shock waves in the case of compressible fluids. Similarly, the speed of the vane leading edges cannot be increased above the critical velocity without creating turbulence in the flow in the case of incompressible fluids. Accordingly, the obtainable ram pressure rise from this embodiment will have a certain upper limit.

To further increase the obtainable static pressure rise, further vanes, arranged in one or more concentric sets, inward of the periphery, may be used, with the design and operation of the further vanes being quite similar to those of the single stage embodiment discussed herein before, so that in operation, the fluid in the space relatively radially outwards of each of the vane sets is rammed into the inlets of the diverging channels formed between the vanes, and is gradually displaced to the space relatively radially inwards of the set of vanes while being diverged. The overall ram pressure rise in the space relatively radially inwards of the innermost set of vanes, will equal the multiplication of the ram pressure rises obtained from the successive concentric sets of vanes.

In another embodiment, the rotary ram fluid pressurizing machine comprises a stationary casing having an inlet passage for admission of fluid and an exit passage for discharge of the pressurized fluid; a drive shaft for rotation in a given direction inside the casing supported by an arrangement of bearings, and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes one disk surrounding the drive shaft and lying in a plane transverse to the rotational axis of the drive shaft, and secured for rotation with it, and a plurality of vanes arranged circumferentially within the annular space defined in-between one of the surfaces of the disk and the opposing part of the inner surface of the casing. Each of the vanes has a first edge attached to the related inner surface of the disk, a second free edge, a relatively radially inward leading edge or tip and a relatively radially outward trailing edge or tail, with each vane curved preferably smoothly from its leading edge towards its trailing edge. The average angles of inclination of the successive portions of the vane with respect to a plane comprising the midpoint of the vane and perpendicular to a radial plane including the rotational axis of the rotor and the midpoint of the vane decreases gradually from the leading edge towards the trailing edge, within a range from about +56 to about -20 degrees. Each vane has a convex displacing surface and a concave surface, with the opposing parts of the surfaces of each two adjacent vanes defining a channel between them, with the channel confined by a part of the concave surface of one vane and its opposing part of the convex surface of an adjacent vane. The rest of the concave surface freely communicates with the space relatively radially inwards of the vanes, and the rest of the convex surface freely communicates with the space relatively radially outwards of the vanes. Accordingly, the channel has an inlet communicating with the space relatively radially inwards of the vanes, and an outlet communicating with the space relatively radially outwards of the vanes. The boundaries of the channel are formed of the opposing parts of the surfaces of the two adjacent vanes and of the opposing parts of the surfaces of the disk and the casing related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes, with the channel diverging from its inlet towards its outlet. It should be noted that the part of the surface of the casing sharing in the formation of the boundaries of the channel is continuously changing during operation.

The divergence of the channel is provided by designing the boundaries confining said channel between them so that: 1) the axial width of the channel, and/or 2) the width between the opposing parts of the surfaces of the two adjacent vanes confining the channel between them increase preferably gradually from the inlet of the channel towards the outlet, and hence, the cross-sectional area of the channel increases preferably gradually from the inlet towards the outlet.

The gradual increase in the axial width of the channel is provided by designing the part of the surface of the disk related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes so that it is sloping preferably gradually from the inlet of the channel towards the outlet. The gradual increase in the width between the opposing parts of the surfaces of the two adjacent vanes is provided by designing the vanes with suitable angles of inclination at their different parts according to the desired rate of divergence of the channels described above.

In operation, the fluid in the space relatively radially inwards of the vanes is rammed into the diverging channels, formed in-between the circumferentially arranged vanes, and is gradually displaced to the space relatively radially outwards of the vanes, while being diverged. This results in a rise in the static pressure energy of the fluid within the diverging channels.

The volumetric capacity of a rotary ram fluid pressurizing machine depends on the number of diverging channels confined between the vanes, their dimensions, and the speed of the vanes leading edges. To increase the volumetric capacity without marked increase in the height of the vanes and to avoid the formation of excessive centrifugal and bending stresses, a further level of vanes arranged circumferentially within the annular space defined in-between the other surface of the disk and its opposing part of the inner surface of the casing may optionally be used, with each of the vanes having an edge attached to its related surface of the disk, and a free edge. The design and operation of the vanes of the further level are quite similar to those of the single leveled embodiment discussed herein before. Opening(s) in the disk(s) portion confined between the circumferentially arranged vanes and the drive shaft may be provided, to provide functional communication between the sub-spaces formed inside the rotor.

The speed of the vane trailing edges cannot be increased above the speed of sound without the formation of shock waves in the case of compressible fluids. Similarly, the speed of the vane trailing edges cannot be increased above the critical velocity without creating turbulence in the flow in the case of incompressible fluids. Accordingly, the obtainable ram pressure rise from this embodiment will have a certain upper limit.

To further increase the obtainable static pressure rise, further vanes, arranged in one or more concentric sets, inward of the periphery, may be used, with the design and operation of the further vanes being quite similar to those of the single stage embodiment discussed herein before, so that in operation, the fluid in the space relatively radially inward of each of the vane sets is rammed into the inlets of the diverging channels formed between the vanes, and is gradually displaced to the space relatively radially outwards of the set of vanes while being diverged. The overall ram pressure rise in the space relatively radially outwards of the outermost set of vanes, will equal the multiplication of the ram pressure rises obtained from the successive concentric sets of vanes.

In the previous embodiments, the attachment of the vane edges to their related surfaces of the disks may be by casting the disk integrally with the vanes, or by fastening the vanes to the disk by pressurized fitting of the vane edges into matching grooves in the related surface of the disk, by bolts, or the disk and vanes may be machined from a single forging. Such attachment means are well known to those of ordinary skill in the art.

Sealing means may be provided at one or more sites, in the clearance between the relatively inner surface of the stationary casing and its related opposing surface(s) of the disk(s) of the rotor assembly, to minimize or prevent the back flow of the pressurized fluid from the exit passage(s) to the inlet passage(s). The sealing means may be of the contact or labyrinth type, according to the type of the fluid being pressurized and the developed pressure gradient. Such sealing means are well known to those of ordinary skill in the art.

The resulting ram pressure rise depends on the speed of the vane leading edges, which depends on the rotational speed of the rotor assembly and its dimensions, noting that the speed of the vane leading edges must be kept within the subsonic range, in case of compressible fluids, to avoid the formation of shock waves, which if formed, will interfere with the feeding of the fluid to the inlets of the diverging channels confined between the vanes, and below the critical velocity, in case of incompressible fluids, to avoid the turbulence in the flow.

The rate of divergence of the channels, as well as the curvature of the vanes, are maintained within the practical limits preventing the separation of the rammed fluid from the boundaries of the diverging channels. Such practical limits depends on the type of the fluid to be pressurized, and are well known to those of ordinary skill in the art.

In the previous embodiments, most of the obtainable static pressure rise occurs while the fluid is rammed through the diverging channels from their inlets to their outlets, with a small fraction of further static pressure rise obtained by diffusion within the space communicating with the outlets of the diverging channels. Fluid directing vanes may be provided in the space communicating with the outlets of the diverging channels, to smooth the flow of fluid within it, and hence, improve the overall efficiency.

The reaction force of the fluid acting on the displacing surface of each of the vanes can be resolved into two components; a radial component and a tangential component, relative to an imaginary circular plane intersecting the vane and concentric with the shaft of the rotor assembly, with the radial components of the reaction forces acting on the vanes of each of the sets being neutralized by one another, so, in operation, the power consumed by the rotor assembly is only utilized in overcoming the tangential components of the reaction forces acting on the displacing surfaces of the vanes, in addition to the mechanical and fluid frictional forces, with the efficiency of the rotary ram fluid pressurizing machine provided in the present invention, being higher than the efficiency of other conventional fluid pressurizing machines.

Also, as minimal acceleration of the fluid occurs within the diverging channels, in the form of gradual displacement in either a relatively radially inward or a relatively radially outwards direction, according to the type of the rotary ram fluid pressurizing machine used, the resulting rise in the temperature of the pressurized fluid will be minimal, with marked improvement in the efficiency of subsequent compression, when needed, and which enables the recovery of more heat energy from the exhaust gases, when used in gas turbine engines provided with heat exchangers, which will decrease the overall heat energy emission from the power plant.

According to the purpose for which the fluid is pressurized, the discharge of the provided pressurized fluid through the exit passage(s) may be intermittent, i.e., when used for supercharging reciprocating internal combustion engines, and the like, or continuous, which may be regulated by the pressure gradient between the fluid inside and outside the exit passage(s) e.g. when used in pumps or with propulsive nozzles, or means for rated accelerated discharge of the pressurized fluid being provided e.g. when used in gas turbine engines and the like, with the optimum pressure rise inside the exit passage(s) obtained when the rate of discharge of the pressurized fluid is equal to the rate at which it is being provided.

BRIEF DESCRIPTION OF THE DRAWINGS

The description of the objects, features and advantages of the present invention, will be more fully appreciated by reference to the following detailed description of the exemplary embodiments in accordance with the accompanying drawings, wherein:

Fig. 1 is a sectional view in a schematic representation of an exemplary embodiment of a rotary ram compressor, in accordance with the present invention.

Fig. 2 is a cross sectional view, taken at the plane of line **2 -2** in **Fig. 1.**

Fig. 3 is a partial cross sectional view, taken at the plane of line **3 - 3** in **Fig. 2.**

Fig. 4 is a sectional view in a schematic representation of an exemplary embodiment of another rotary ram compressor, in accordance with the present invention.

Fig. 5 is a cross sectional view, taken at the plane of line **5 - 5** in **Fig. 4.**

Fig. 6 is a partial cross sectional view, taken at the plane of line **6 - 6** in **Fig. 5**.

Fig. 7 is a sectional view in a schematic representation of an exemplary embodiment of a rotary ram pump, in accordance with the present invention, wherein the provided pressurized fluid is discharged through a propelling nozzle.

Fig. 8 is a cross sectional view, taken at the plane of line **8 - 8** in **Fig. 7.**

Fig. 9 is a sectional view in a schematic representation of an exemplary embodiment of a multi-level, multi-stage rotary ram compressor, in accordance with the present invention.

Fig. 10 is a cross sectional view, taken at the plane of line **10 - 10** in **Fig. 9.**

Fig. 11 is a partial sectional view in a schematic representation of an exemplary embodiment of a rotary ram pump, in accordance with the present invention.

Fig. 12 is a partial cross sectional view, taken at the plane of line **12 - 12** in **Fig. 11.**

Fig. 13 is a sectional view in a schematic representation of an exemplary embodiment of a two-stage rotary ram vacuum pump, in accordance with the present invention.

Fig. 14 is a cross sectional view, taken at the plane of line **14 - 14** in **Fig. 13.**

Fig. 15 is a sectional view in a schematic representation of an exemplary embodiment of a combined rotary ram compressor, in accordance with the present invention.

Fig. 16 is a cross sectional view, taken at the plane of line **16 - 16** in **Fig. 15.**

Fig. 17 is a cross sectional view, taken at the plane of line **17 - 17** in **Fig. 15.**

Figs. 18, 19 are sectional views in a schematic representation of an exemplary embodiment of a variable capacity rotary ram compressor, in accordance with the present invention, in the full and partial capacity operating positions, respectively.

Figs. 20, 21 are sectional views in a schematic representation of an exemplary embodiment of a variable capacity rotary ram pump, in accordance with the present invention, in the full and partial capacity operating positions, respectively.

Figs. 22 - 24 are sectional views in a schematic representation of an exemplary embodiment of a rotary ram pump having an axially movable rotor assembly, and two discharge passages, at different axial positions of the rotor assembly.

Figs. 25 - 29 are schematic representations of alternatives in which the diverging channels confined between the opposing parts of the surfaces of the adjacent vanes of a rotary ram fluid pressurizing machine in accordance with the present invention, may be designed.

Fig. 30 is a sectional view in a schematic representation of an exemplary embodiment of another rotary ram compressor, in accordance with the present invention.

Fig. 31 is a sectional view in a schematic representation of an exemplary embodiment of another rotary ram pump, in accordance with the present invention, wherein the provided pressurized fluid is discharged through a propelling nozzle.

Fig. 32 is a sectional view in a schematic representation of an exemplary embodiment of another rotary ram pump, in accordance with the present invention.

Fig. 33 is a sectional view in a schematic representation of an exemplary embodiment of another rotary ram compressor, in accordance with the present invention.

Fig. 34 illustrates the angles of inclination of the vanes of the rotor of a rotary ram fluid pressurizing machine, according to the present invention.

Fig. 35 illustrates the angles of inclination of the vanes of the rotor of another rotary ram fluid pressurizing machine, according to the present invention.

DETAILED DESCRIPTION

Fig. 1 is a sectional view in a schematic representation of an embodiment in accordance with the present invention of a rotary ram compressor.

The main components of the rotary ram compressor in this embodiment are a stationary casing **21** having an inlet passage **22** for admission of compressible fluid **23** e.g., gas, or vapor, or a mixture of gases and vapors, provided with means for filtering the incoming fluid, and an exit passage **24** for discharge of the pressurized fluid **25**; a drive shaft **26** supported for rotation in a given direction inside the casing by an arrangement of bearings **27**, and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes a first disk **28**, a second disk **29**, and a plurality of vanes **30** arranged circumferentially within the annular space defined in-between the relatively inner surfaces of the disks, with both of the disks being secured for rotation with the drive shaft. Each of the disks has a relatively inner surface **31**, forming one of the boundaries of the space confined inside the rotor, and a relatively outer surface **32** facing its adjacent part of the casing. Each of the circumferentially arranged vanes has a first edge **33** attached to the inner surface of the first disk, a second edge **34** attached to the inner surface of the second disk. As shown in **Fig. 2** which is a cross sectional view, taken at the plane of line **2 - 2** in **Fig. 1**, each of the vanes has a relatively radially outwards leading edge or tip **35**, and a relatively radially inward trailing edge or tail **36**. Each vane is preferably smoothly curved from its leading edge **35** towards its trailing edge **36**. The average angles of inclination of the successive portions of the vane with respect to a plane comprising the midpoint of the vane and perpendicular to a radial plane including the rotational axis of the rotor and the midpoint of the vane decreases gradually from its leading edge towards its trailing edge, within a range from about +20 to about -48 degrees Each vane has a concave displacing surface **37** and a convex surface **38**, with the opposing parts of the surfaces of each two adjacent vanes defining a channel **39** between them. The channel is confined by a part of the concave surface of one vane and its opposing part of the convex surface of its adjacent vane. The rest of the concave surface freely communicates with the space **40** relatively radially inwards of the vanes, and the rest of the convex surface freely communicates with the space **41** relatively radially outwards of the vanes. The channel has an inlet **42** communicating with the space relatively radially outwards of the vanes, and an outlet **43** communicating with the space relatively radially inwards of the vanes. The boundaries of the channel are formed of the opposing parts of the surfaces of the two adjacent vanes and of the two opposing parts of the inner surfaces of the disks related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes. As shown in **Fig. 3** which is a cross sectional view, taken at the plane of line **3 - 3** in **Fig. 2**, each of the opposing parts of the inner surfaces of the disks confined between the opposing parts of the surfaces of the two adjacent vanes **44,45** is sloped, so that the axial width of the channel increases gradually from the inlet of the channel towards its outlet. Accordingly, the channel diverges from its inlet towards its outlet.

In operation, the fluid in the space **41** relatively radially outwards of the vanes is rammed into the diverging channels **39** confined in-between the opposing parts of the surfaces of the circumferentially arranged vanes, and is gradually displaced to the space **40** relatively radially inwards of the vanes, while being diverged, resulting in a rise in the static pressure energy of the fluid within the diverging channels **39**.

The pressurized fluid is discharged through openings **46** in one of the disks **29**, within the disk's portion confined between the vanes **30** and the drive shaft **26**, and communicating with the exit passage in the casing **21**. Labyrinth sealing **47** is provided in the clearance between the outer surface **32** of the second disk and its opposing inner surface of the stationary casing, to minimize the back flow of the pressurized fluid from the exit passage **24** to the inlet passage **22**.

The resulting ram pressure rise in this embodiment depends on the speed of the vane leading edges **35**, which depends on the rotational speed of the rotor assembly, and its dimensions. The speed of the vane leading edges must be kept within the subsonic range, to avoid the formation of shock waves, which if formed, will interfere with the feeding of the fluid to the inlets **42** of the diverging channels **39**.

In this embodiment, most of the obtainable static pressure rise occurs while the fluid is rammed through the channels from their inlets **42** to their outlets **43**, with only a small fraction of the static pressure rise obtained by diffusion within the space **40** relatively radially inwards of the vanes.

The rotary ram compressor provided in the present embodiment can be used in applications wherein intermittent supply of compressed fluid is needed, e.g., supercharging of reciprocating internal combustion engines, and the like, or alternatively for applications wherein continuous supply of compressed fluid is needed.

Fig. 4 is a sectional view in a schematic representation of another embodiment in accordance with the present invention of a rotary ram compressor.

The main components of the rotary ram compressor in this embodiment are a stationary casing **51** having an inlet passage **52** for admission of compressible fluid, **53** e.g., gas, or vapor, or a mixture of gases and vapors, provided with means for filtering the incoming fluid, and an exit passage **54** for discharge of the pressurized fluid **55**; a drive shaft **56** supported for rotation in a given direction inside the casing by an arrangement of bearings **57,** and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes a first disk **58,** a second disk **59,** and a plurality of vanes **60** arranged circumferentially within the annular space defined in-between the relatively inner surfaces of the disks. The first disk is secured for rotation with the drive shaft. Each of the disks has a relatively inner surface **61,** forming one of the boundaries of the space confined inside the rotor, and a relatively outer surface **62** facing its adjacent part of the casing. Each of the circumferentially arranged vanes has a first edge **63** attached to the inner surface of the first disk and a second edge **64** attached to the inner surface of the second disk. As shown in **Fig. 5** which is a cross sectional view, taken at the plane of line **5 - 5** in **Fig. 4**, each of the vanes has a relatively radially outwards leading edge or tip **65** and a relatively radially inward trailing edge or tail **66.** Each vane is preferably smoothly curved from its leading edge **65** towards its trailing edge **66**. The average angles of inclination of the successive portions of the vane with respect to a plane comprising the midpoint of the vane and perpendicular to a radial plane including the rotational axis of the rotor and the midpoint of the vane decreases gradually from its leading edge towards its trailing edge within a range from about +22 to about -47 degrees. Each vane has a concave displacing surface **67** and a convex surface **68**, with the opposing parts of the surfaces of each two adjacent vanes defining a channel **69** between them. The channel is confined by a part of the concave surface of a vane and its opposing part of the convex surface of its adjacent vane. The rest of the concave surface freely communicates with the space **70** relatively radially inwards of the vanes. The rest of the convex surface freely communicates with the space **71** relatively radially outwards of the vanes. The channel has an inlet **72** communicating with the space relatively radially outwards of the vanes, and an outlet **73** communicating with the space relatively radially inwards of the vanes. The boundaries of the channel are formed of the opposing parts of the surfaces of the two adjacent vanes and of the two opposing parts of the inner surfaces of the disks related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes. The width between the opposing parts of the surfaces of the two adjacent vanes increases gradually from the inlet of the channel **72** towards its outlet **73**. As shown in **Fig. 6** which is a cross sectional view, taken at the plane of line **6 - 6** in **Fig. 5**, the part of the inner surface of the second disk confined between the opposing parts of the surfaces of the two adjacent vanes **74** is sloped, so that the axial width of the channel increases gradually from the inlet of the channel towards its outlet. Accordingly, the channel diverges from its inlet towards its outlet.

In operation, the fluid in the space **71** relatively radially outwards of the vanes is rammed into the diverging channels **69** confined in-between the opposing parts of the surfaces of the circumferentially arranged vanes, and is gradually displaced to the space **70** relatively radially inwards of the vanes, while being diverged, resulting in a rise in the static pressure energy of the fluid within the diverging channels **69**. Labyrinth sealing **75** is provided in the clearance between the outer surface of the second disk **59** and its opposing inner surface of the stationary casing, to minimize the back flow of the pressurized fluid from the exit passage **54** to the inlet passage 52.

The resulting ram pressure rise in this embodiment depends on the speed of the vane leading edges **65,** which depends on the rotational speed of the rotor assembly, and its dimensions. Note that the speed of the vane leading edges must be kept within the subsonic range, to avoid the formation of shock waves, which if formed, will interfere with the feeding of the fluid to the inlets **72** of the diverging channels **69.**

In this embodiment, most of the obtainable static pressure rise occurs while the fluid is rammed through the channels from their inlets **72** to their outlets **73,** with only a small fraction of the static pressure rise obtained by diffusion within the space **70** relatively radially inwards of the vanes.

The rotary ram compressor provided in the present embodiment can be used in applications wherein intermittent supply of compressed fluid is needed, e.g., supercharging of reciprocating internal combustion engines, and the like, or for applications wherein continuous supply of compressed fluid is needed.

Fig. 7 is a sectional view in a schematic representation of an embodiment in accordance with the present invention of a rotary ram pump wherein the provided pressurized fluid is discharged through a propelling nozzle. The main components of the rotary ram pump in this embodiment are a stationary casing **81** having an inlet passage **82** for admission of an incompressible fluid, i.e., liquid **83,** an exit passage **84** for discharge of the pressurized fluid **85** and a convergent nozzle **86** freely communicating with the exit passage **84**; a drive shaft **87** supported for rotation in a given direction inside the casing by an arrangement of bearings **88**, and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes a first disk **89**, a second disk **90**, and a plurality of vanes arranged circumferentially in two axially stacked levels **91, 92** within the annular space defined in-between the relatively inner surfaces of the disks, with an intervening disk **93** between the vane levels. All of the disks **89, 90, 93** are secured for rotation with the drive shaft. Each of the disks **89, 90** has a relatively inner surface **94, 95** forming one of the boundaries of the space confined inside the rotor, and a relatively outer surface **96, 97** facing its adjacent part of the casing. Each of the circumferentially arranged vanes of the first level **91** has a first edge **98** attached to the inner surface of the first disk **94** and a second edge **99** attached to its related surface of the intervening disk **93**. Each of the circumferentially arranged vanes of the second level **92** has a first edge **100** attached to the inner surface of the second disk **95**, and a second edge **101** attached to its related surface of the intervening disk **93**. As shown in **Fig. 8** which is a cross sectional view, taken at the plane of line **8 - 8** in **Fig. 7**, each of the vanes has a relatively radially outwards leading edge or tip **102**, and a relatively radially inward trailing edge or tail **103**. Each vane is preferably smoothly curved from its leading edge **102** towards its trailing edge **103**. The average angles of inclination of the successive portions of the vane with respect to a plane comprising the midpoint of the vane and perpendicular to a radial plane including the rotational axis of the rotor and the midpoint of the vane decreases gradually from its leading edge towards its trailing edge within a range from about +22 to about -42 degrees. Each vane has a concave displacing surface **104** and a convex surface **105**, with the opposing parts of the surfaces of each two adjacent vanes defining a channel **106** between them. The channel is confined by a part of the concave surface of one vane and its opposing part of the convex surface of an adjacent vane. The rest of the concave surface freely communicates with the space **107** relatively radially inward of the vanes. The rest of the convex surface freely communicates with the space **108** relatively radially outward of the vanes. The channel has an inlet **109** communicating with the space **108** relatively radially outwards of the vanes, and an outlet **110** communicating with the space **107** relatively radially inwards of the vanes. The boundaries of the channel are formed of the opposing parts of the surfaces of the two adjacent vanes and of the two opposing parts of the inner surfaces of the disks related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes **111, 112**. The width between the opposing parts of the surfaces of the two adjacent vanes increases gradually from the inlet of the channel **109** towards its outlet **110**. Accordingly, the channel diverges from its inlet towards its outlet.

In operation, the fluid in the space relatively radially outwards of the vanes **108** is rammed into the diverging channels confined in-between the circumferentially arranged vane levels **91, 92** and is gradually displaced to the space **107** relatively radially inwards of the vanes , while being diverged, resulting in a rise in the static pressure energy of the fluid within the diverging channels. The pressure energy in the pressurized fluid is then converted into kinetic energy within the convergent nozzle **86** which is freely communicating with the exit passage 84.

Means for contact sealing **113** are provided in the clearance between the outer surfaces of the disks **96,97** and their opposing inner surfaces of the stationary casing, to minimize or prevent the back flow of the pressurized fluid from the exit passage **84** to the inlet passage **82.** A number of holes **114** are bored through the first disk **89** to equalize the pressure of the fluid on both sides of the disk, and thus, minimize or alleviate the axial forces transmitted to the bearing **88** through the drive shaft **87.**

The rotary ram pump provided in the present embodiment, wherein the provided pressurized fluid is discharged through a propelling nozzle, can be used in the propulsion of different types of sea vehicles, with a propulsive efficiency more than that provided by other conventional means, e.g., propellers and the like.

Fig. 9 is a sectional view in a schematic representation of another embodiment in accordance with the present invention, a multi-level, multi-stage rotary ram compressor.

The main components of the rotary ram compressor in this embodiment are a stationary casing **121** having an inlet passage **122** for admission of compressible fluid **123**, e.g., gas, or vapor, or a mixture of gases and vapors, provided with means for filtering the incoming fluid, and an exit passage **124** for discharge of the pressurized fluid **125;** a drive shaft **126** supported for rotation in a given direction inside the casing by an arrangement of bearings **127,** and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes a first disk **128,** a second disk **129,** and a plurality of vanes arranged in three axially stacked levels within the annular space defined in-between the relatively inner surfaces of the disks. Each of the vane levels has three concentric sets of vanes **130, 131, 132,** with two intervening disks **133, 134** between the vane levels. Both of the disks **128, 129** are secured for rotation with the drive shaft **126**. Each of the vanes has two edges, each attached to its related surface of either one of the disks or of the intervening disks. As shown in **Fig. 10** which is a cross sectional view, taken at the plane of line **10 - 10** in **Fig. 9**, each of the vanes has a relatively radially outwards leading edge or tip **135,** and a relatively radially inward trailing edge or tail **136** with each vane preferably smoothly curved from its leading edge **135** towards its trailing edge **136.** The average angles of inclination of the successive portions of the vane with respect to a plane comprising the midpoint of the vane and perpendicular to a radial plane including the rotational axis of the rotor and the midpoint of the vane decreases gradually from its leading edge towards its trailing edge, within a range from about +26 to about -40 degrees. Each vane has a concave displacing surface **137** and a convex surface **138.** Opposing parts of the surfaces of each two adjacent vanes define a channel **139** between them, with the channel confined by a part of the concave surface of one vane and its opposing part of the convex surface of its adjacent vane. The rest of the concave surface freely communicates with the space **140** relatively radially inwards of the vanes, and the rest of the convex surface freely communicates with the space **141** relatively radially outward of the vanes, with the channel **139** having an inlet **142** communicating with the space **141** relatively radially outwards of the vanes, and an outlet **143** communicating with the space **140** relatively radially inward of the vanes. The boundaries of the channel are formed of: 1) the opposing parts of the surfaces of the two adjacent vanes; and 2) the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes. Each of the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of each two adjacent vanes of the relatively outermost sets of vanes **144, 145** are sloped so that the axial width of each of the channels confined between the vanes of the outermost sets of vanes **130** increases gradually from the inlet of the channel towards its outlet. The width between the opposing parts of the surfaces of each two adjacent vanes of the relatively inner sets of vanes **131, 132** increases gradually from the inlet of the channel confined between them towards its outlet, so that each of the channels confined between the adjacent vanes diverges from its inlet towards its outlet.

In operation, the fluid in the space relatively radially outwards of each of the concentric sets of vanes is rammed into the diverging channels confined in-between the vanes of each of the concentric sets, and is gradually displaced to the space relatively radially inwards of the vanes, while being diverged, resulting into a rise in the static pressure energy of the fluid within the diverging channels. The overall ram pressure rise in the space **132** relatively radially inward of the innermost set of vanes will equal the multiplication of the ram pressure rises obtained from the successive concentric sets of vanes.

A ducted fan **146** is used for rated accelerated discharge of the provided pressurized fluid **125**, with labyrinth sealing **147** being provided in the clearance between the outer surface of the second disk **129** and its opposing inner surface of the stationary casing, to minimize the back flow of the pressurized fluid from the exit passage **124** to the inlet passage **122.**

The rotary ram compressor provided in the present embodiment may be used in the applications wherein a continuous flow of pressurized fluid is needed, e.g., gas turbine engines, and the like.

Fig. 11 is a partial sectional view in a schematic representation of an exemplary embodiment of a rotary ram pump, in accordance with the present invention. The main components of the rotary ram pump in this embodiment are a stationary casing **151** having an inlet passage **152** for admission of fluid **153** and a volute chamber **154** communicating with an exit passage **155** for discharge of the pressurized fluid **156**; and as shown in **Fig. 12,** which is a partial cross sectional view, taken at the plane of line **12 - 12** in **Fig. 11,** a drive shaft **157** supported for rotation in a given direction inside the casing by an arrangement of bearings **158,** and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes a first disk **159,** a second disk **160,** and a plurality of vanes **161** arranged circumferentially within the annular space defined in-between the relatively inner surfaces of the disks. Both of the disks are secured for rotation with the drive shaft **157.** Each of the disks has a relatively inner surface **162,** forming one of the boundaries of the space confined inside the rotor, and a relatively outer surface **163** facing its adjacent part of the casing. Each of the circumferentially arranged vanes has a first edge attached to the inner surface of the first disk **164,** a second edge attached to the inner surface of the second disk **165,** a relatively radially inward leading edge or tip **166** and a relatively radially outwards trailing edge or tail **167.** Each vane is preferably smoothly curved from its leading edge towards its trailing edge, with the average angles of inclination of the successive portions of the vane with respect to a plane comprising the midpoint of the vane and perpendicular to a radial plane including the rotational axis of the rotor and the midpoint of the vane decreasing gradually from its leading edge towards its trailing edge, within a range from about +48 to about -13 degrees. Each vane has a convex displacing surface **168** and a concave surface **169**, with the opposing parts of the surfaces of each two adjacent vanes defining a channel **170** between them. The channel is confined by a part of the concave surface of one vane and its opposing part of the convex surface of an adjacent vane. The rest of the concave surface freely communicates with the space **171** relatively radially inwards of the vanes, and the rest of the convex surface freely communicates with the space **172** relatively radially outwards of the vanes. The channel has an inlet **173** communicating with the space **171** relatively radially inwards of the vanes, and an outlet **174** communicating with the space **172** relatively radially outwards of the vanes. The boundaries of the channel are formed of the opposing parts of the surfaces of the two adjacent vanes and of the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes **175, 176**. The width between the opposing parts of the surfaces of the two adjacent vanes increases gradually from the inlet of the channel towards its outlet, so that the channel diverges from its inlet towards its outlet.

In operation, the fluid in the space relatively radially inward of the vanes is rammed into the diverging channels **170,** and is gradually displaced to the space relatively radially outwards of the vanes, while being diverged, resulting in a rise in the static pressure energy of the fluid within the diverging channels.

The pressurized fluid is discharged through the volute chamber **154** communicating with the exit passage **155,** with means for contact sealing **177** being provided in the clearance between the outer surface of the second disk **160** and its opposing inner surface of the stationary casing, to minimize the back flow of the pressurized fluid from the volute chamber **154** to the inlet passage **152**.

The resulting ram pressure rise in this embodiment, depends on the speed of the vane leading edges **166**, which depends on the rotational speed of the rotor assembly, and its dimensions.

The rotary ram pump provided in the present embodiment can be used to move or lift incompressible fluids, i.e., liquids, with an overall efficiency more than that of the conventionally used types of rotary pumps.

Fig. 13 is a sectional view in a schematic representation of an embodiment in accordance with the present invention of a two-stage rotary ram vacuum pump.

The main components of the rotary ram vacuum pump in this embodiment are a stationary casing **181** having an inlet passage **182** communicating with the container to be vacuumed, with an automatic valve **183** in-between, and an exit passage **184** for discharge of the vacuumed fluid **185;** a drive shaft **186** supported for rotation in a given direction inside the casing by an arrangement of bearings **187,** and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes a first disk **188**, a second disk **189,** and a plurality of vanes arranged in two concentric sets **190,191** within the annular space defined in-between the relatively inner surfaces of the disks. Both of the disks **188, 189** are secured for rotation with the drive shaft **186**. Each of the vanes has two edges each attached to the relatively inner surface of its related disk. As shown in **Fig. 14,** which is a cross sectional view, taken at the plane of line **14 - 14** in **Fig. 13**, each of the vanes has a relatively radially inward leading edge or tip **192,** and a relatively radially outward trailing edge or tail **193.** The design and operation of the vanes of each of the concentric sets are quite similar to those of the vanes of the embodiment of **Figs. 11,12.**

In operation, the compressible fluid in the space relatively radially inward of each of the concentric sets of vanes is rammed into the diverging channels confined in-between the vanes **190, 191** of each of the concentric sets, and is gradually displaced to the space relatively radially outwards of the vanes while being diverged, resulting in a rise in the static pressure energy of the fluid within the diverging channels, so that the compressible fluid within the inlet passage **182** is rammed out through the diverging passages confined between the vanes, and discharged through the exit passage **184,** with relative decrease in the pressure of the fluid within the inlet passage **182,** which is reflected in the container communicating with it.

The vacuum level provided by the present embodiment depends on the speed of the vane leading edges **192,** which depends on the rotational speed of the rotor assembly, and its dimensions.

Fig. 15 is a sectional view in a schematic representation of an exemplary embodiment of a combined rotary ram compressor, in accordance with the present invention. The main components of the combined rotary ram compressor in this embodiment are a stationary casing **201** having an inlet passage **202** for admission of compressible fluid, e.g., gas, or vapor, or a mixture of gases and vapors **203**, and an exit passage **204** for discharge of the pressurized fluid **205;** a drive shaft **206** supported for rotation in a given direction inside the casing by an arrangement of bearings **207,** and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes a first disk **208,** a second disk **209,** a third disk **210.** The rotor assembly is functionally divided into two serially disposed compressor stages, a first stage in-between the first disk **208** and the second disk **209,** and a second stage in-between the second disk **209** and the third disk **210.** The first compressor stage comprises a plurality of vanes arranged in two axially stacked levels, with the vanes of each of the levels arranged in three concentric sets **211, 212, 213,** with a fixed intervening disk **214** between the vane levels. The second compressor stage comprises a plurality of vanes arranged in three concentric sets **215, 216, 217,** with the three disks **208, 209, 210** being secured for rotation with the drive shaft **206.** The fixed intervening disk is attached to the casing, with an arrangement of bearings provided between the disk and the drive shaft. Each of the vanes of the first compressor stage has two edges, a first edge attached to its related surface of either one of the first and second disks **208,209,** and a second free edge. As shown in **Fig. 16** which is a cross sectional view, taken at the plane of line **16 - 16** in **Fig. 15,** each of the vanes of the first stage **211, 212, 213,** has a relatively radially inward leading edge or tip **218,** and a relatively radially outwards trailing edge or tail **219.** Each vane preferably smoothly curves from its leading edge **218** towards its trailing edge **219.** The average angles of inclination of the successive portions of the vane with respect to a plane comprising the midpoint of the vane and perpendicular to a radial plane including the rotational axis of the rotor and the midpoint of the vane decreases gradually from its leading edge towards its trailing edge, within a range from about +56 to about -20 degrees. Each vane has a convex displacing surface **220,** and a concave surface **221**, with the opposing parts of the surfaces of each two adjacent vanes defining a channel **222** between them. The channel is confined by a part of the concave surface of one vane and its opposing part of the convex surface of its adjacent vane. The rest of the concave surface freely communicates with the space **223** relatively radially inwards of the vanes, and the rest of the convex surface freely communicates with the space **224** relatively radially outwards of the vanes. The channel has an inlet **225** communicating with the space **223** relatively radially inwards of the vanes, and an outlet **226** communicating with the space relatively radially outwards of the vanes **224**. The boundaries of the channel are formed of the opposing parts of the surfaces of the two adjacent vanes and of the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes. Each of the opposing parts of the disks' surfaces confined between the opposing parts of the surfaces of the adjacent vanes of the relatively innermost sets of vanes **227, 228** are sloped, so that the axial width of each of the channels confined between the vanes of the innermost sets of vanes **213** increases gradually from the inlet of the channel towards its outlet. The width between the opposing parts of the surfaces of each two adjacent vanes of the relatively outer sets of vanes **211, 212** increases gradually from the inlet of the channel confined between them towards its outlet, so that each of the channels confined between the adjacent vanes diverges from its inlet towards its outlet. Each of the vanes of the second compressor stage has two edges, each attached to the related surface of either of the second or third disks **209,210.** As shown in **Fig. 17,** which is a cross sectional view taken at the plane of line **17 - 17** in **Fig. 15,** each of the vanes of the second stage **215, 216, 217** has a relatively radially outwards leading edge or tip **229** and a relatively radially inward trailing edge or tail **230.** Each vane preferably smoothly curves from its leading edge **229** towards its trailing edge **230.** The average angles of inclination of the successive portions of the vane with respect to a plane comprising the midpoint of the vane and perpendicular to a radial plane including the rotational axis of the rotor and the midpoint of the vane decreases gradually from its leading edge towards its trailing edge, within a range from about +22 to about -45 degrees. Each vane has a concave displacing surface **231** and a convex surface **232**, with the opposing parts of the surfaces of each two adjacent vanes defining a channel **233** between them. The channel is confined by a part of the concave surface of one vane and its opposing part of the convex surface of an adjacent vane. The rest of the concave surface freely communicates with the space **234** relatively radially inwards of the vanes. The rest of the convex surface freely communicates with the space **235** relatively radially outwards of the vanes. The channel has an inlet **236** communicating with the space **235** relatively radially outwards of the vanes, and an outlet **237** communicating with the space **234** relatively radially inwards of the vanes. The boundaries of the channel are formed of the opposing parts of the surfaces of the two adjacent vanes and the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes. Each of the parts of the surface of the third disk related to the channels and confined between the opposing parts of the surfaces of the adjacent vanes of the relatively outermost set of vanes **238** are sloped so that the axial width of each of the channels confined between the vanes of the outermost set of vanes **215** increases gradually from the inlet of the channel towards its outlet. The width between the opposing parts of the surfaces of each two adjacent vanes of the second compressor stage increases gradually from the inlet of the channel confined between them towards its outlet, so that each of the channels confined between the adjacent vanes diverges from its inlet towards its outlet. In operation, the fluid in the inlet passage **202** is rammed through the diverging channels confined in-between the concentric sets of vanes of the first compressor stage to an intermediate passage **239**, from which the partially pressurized fluid **240** is rammed through the diverging channels confined in-between the concentric sets of vanes of the second compressor stage to the exit passage **204**. The overall ram pressure rise in the exit passage **204** will equal the multiplication of the ram pressure rises obtained from the two compressor stages.

A ducted fan **241** is used for rated accelerated discharge of the provided pressurized fluid **205**, with labyrinth sealing **242** provided in the clearance between the relatively outer surfaces of the first and third disks **208,210** and their opposing inner surfaces of the stationary casing, to minimize the back flow of the pressurized fluid from the exit passage **204** to the inlet passage **202**, through the intermediate passage **239**.

The rotary ram compressor provided in the present embodiment may be used in the applications wherein a continuous flow of pressurized fluid is needed, e.g., gas turbine engines, and the like.

Figs. 18, 19 are sectional views in a schematic representation of an embodiment, in accordance with the present invention, of a variable capacity rotary ram compressor in the full and partial capacity operating positions, respectively.

The main components of the variable capacity rotary ram compressor in this embodiment are a stationary casing **251**, having an inlet passage **252** for admission of the compressible fluid, e.g., gas, or vapor, or a mixture of gases and vapors **253** provided with means for filtering the incoming fluid, and an exit passage **254** for discharge of the pressurized fluid **255**; a first shaft **256** supported for rotation in a given direction in the casing by an arrangement of bearings **257**, and extending to a drive receiving end located outside the casing; a second axially movable shaft **258**, concentric with the first shaft **256**, and supported for rotation within the casing by an axially movable, spring-loaded **259**, a double-sided arrangement of bearings **260**; and a rotor assembly located inside the casing. The rotor assembly include, a first disk **261** secured for rotation with the first shaft **256**, a second disk **262** secured for rotation with the second axially movable shaft **258**, and a plurality of vanes arranged circumferentially within the annular space defined in-between the relatively inner surfaces of the disks. Each of the disks has a relatively inner surface, forming one of the boundaries of the space confined inside the rotor assembly, and a relatively outer surface facing its adjacent part of the casing. Each of the vanes has a first edge **263** attached to the inner surface of the first disk **261**, a second edge **264** forming a male end in fluid tight communication with a female groove **265** in the inner surface of the second disk **262**, a relatively radially outwards leading edge or tip, and a relatively radially inward trailing edge or tail (not shown in the drawing). The design and operation of the circumferentially arranged vanes being quite similar to those of the vanes of the embodiment of **figs. 7,8.**

In operation, the volumetric delivery is regulated by variations in the axial width of the diverging channels confined between the vanes and the inner surfaces of the disks. This is achieved by axially moving the axially movable shaft **258,** with the axial movement of the shaft being transmitted to the second disk **262** mounted on it, which results in changing the axial width between the inner surfaces of the two disks **261,262,** and hence, the axial width of the diverging channels.

The axial movement of the axially movable shaft can be provided by mechanical, electro-mechanical, electrical, hydraulic, or pneumatic means. Such means are well known to those of ordinary skill in the art.

Figs. 20, 21 are sectional views in a schematic representation of an embodiment, in accordance with the present invention, of a variable capacity rotary ram pump in the full and partial capacity operating positions, respectively.

The main components of the variable capacity rotary ram pump in this embodiment are a stationary casing **271** having an inlet passage **272** for admission of fluid **273,** and an exit passage **274** for discharge of the pressurized fluid **275**; a first axially movable shaft **276** supported for rotation in a given direction in the casing by an arrangement of bearings **277,** and extending to a drive receiving end located outside the casing; a second shaft **278** concentric with the first shaft **276,** and supported for rotation in the casing by a double-sided arrangement of bearings **279**; and a rotor assembly located inside the casing. The rotor assembly includes a first disk 280 secured for rotation with the first axially movable shaft **276,** a second disk **281** secured for rotation with the second shaft **278,** and a plurality of vane arranged circumferentially within the annular space defined in-between the relatively inner surfaces of the disks. Each of the disks has a relatively inner surface, forming one of the boundaries of the space confined inside the rotor assembly, and a relatively outer surface facing its adjacent part of the casing. Each of the vanes has a first edge **282** attached to the inner surface of the first disk **280**, a second edge **283** forming a male end in fluid tight communication with a female groove **284** in the inner surface of the second disk **281,** a relatively radially inward leading edge or tip, and a relatively radially outwards trailing edge or tail (not shown in the drawing). The design and operation of the circumferentially arranged vanes being quite similar to those of the vanes of the embodiment of **Figs. 11,12.**

In operation, the volumetric delivery is regulated by variations in the axial width of the diverging channels confined between the vanes and the inner surfaces of the disks. This is achieved by axially moving the axially movable shaft **276,** with the axial movement of the shaft being transmitted to the disk **280** mounted on it, which results in changing the axial width between the inner surfaces of the two disks **280, 281,** and hence, the axial width of the diverging channels.

The axial movement of the axially movable shaft can be provided by mechanical, electro-mechanical, electrical, hydraulic, or pneumatic means. Such means are well known to those of ordinary skill in the art.

Figs. 22 - 24 are sectional views in a schematic representation of an embodiment in accordance with the present invention of a rotary ram pump having an axially movable rotor assembly, and two discharge passages, at different axial positions of the rotor assembly.

The main components of the rotary ram pump in this embodiment are a stationary casing **291** having inlet passages **292,293** for admission of fluid **294,** and two exit passages **295, 296** in axially stacked relation, and separated by an intermediate ring-shaped septum **297,** with each exit passage having a separate exit port **298,299;** an axially movable drive shaft **300,** supported for rotation in a given direction in the casing at one end by concentric shaft arrangement **301**, and at the other end by an arrangement of bearings **302** allowing for the shaft's axial movement, with the shaft extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing **291.** The rotor assembly includes a first disk **303,** a second disk **304,** and a plurality of vanes arranged circumferentially in two axially stacked levels **305,306** within the annular space defined in-between the relatively inner surfaces of the disks. An intervening disk **307** is disposed between first and second disks **303,304** which are secured for rotation with the axially movable drive shaft **300**. Each of the two disks has a relatively inner surface, forming one of the boundaries of the space confined inside the rotor assembly, and a relatively outer surface facing the disk's adjacent part of the casing. Each of the circumferentially arranged vanes has a first edge, and a second edge, each attached to its related surface of either one of the two disks **303, 304,** or of the intervening disk **307.** The design and operation of the vanes of each of the two circumferentially arranged vane levels **305, 306** are quite similar to those of the vanes of the embodiment of **Figs. 11, 12.**

The openings of the exit ports **299** are provided with spring-loaded valves, which open when the flow of the pressurized fluid is directed through their related exit passages **296**. The exit passages **296** are formed of two parallel tubular chambers, which join together to form an annular passage surrounding the space confining the rotor assembly, and extending to the exit passage **295** which opens through its related annular shaped exit port **298**.

In operation, when this embodiment is used for propelling a sea vehicle or the like, the axial movement of the axially movable shaft **300** is transmitted to the rotor assembly mounted on it. This results in changing the axial position of the peripheral part of the rotor assembly, through which the pressurized fluid **308** is discharged, relative to the two axially stacked exit passages **295, 296.** With this arrangement, the pressurized fluid may be discharged either completely through the first exit passage **295** as shown in **Fig. 22,** or completely through the second exit passages **296** as shown in **Fig. 24.** The former mode, illustrated in **Fig. 22** provides a forward thrust to the propelled vehicle, with the fluid being admitted through the relatively anterior group of inlet passages **293** due to the forward movement of the vehicle. The later mode, illustrated in **Fig 24**, provides a rearward thrust to the propelled vehicle, with the fluid being admitted through the relatively posterior group of inlet passages **292** due to the rearward movement of the vehicle, with opening of the spring-loaded valves of the exit ports **299** under the pressure of the fluid directed through their related exit passages **296**. In a third operating mode, as shown in **Fig. 23**, the thrust is distributed between the two exit passages **295, 296**, with an adjustable ratio, as needed.

The axial movement of the axially movable shaft **300** can be provided by mechanical, electro-mechanical, electrical, hydraulic, or pneumatic means. Such means are well known to those of ordinary skill in the art.

The main advantage of this embodiment, when used for propelling sea vehicles or the like, is that it provides variable levels of thrust reversing, without changing the rotational speed of the driving mechanism, and hence, gas turbine engines with limited variability in their operating rotational speeds can be practically used for propulsion of sea vehicles and the like.

Figs. 25 - 29 are schematic representations of alternative ways in which the diverging channels confined between the opposing parts of the surfaces of each two adjacent vanes of a rotary ram fluid pressurizing machine in accord with the present invention, may be designed.

As discussed herein before, the boundaries of each of the channels are formed of the opposing parts of the surfaces of the two adjacent vanes confining the channel between them **(right front and left rear surfaces of the drawings),** and of the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes.

In **Fig. 25** the divergence of the channel is provided by designing the boundaries confining the channel between them so that the axial width **311** of the channel increases gradually from the inlet **312** of the channel towards its outlet **313**, with the gradual increase in the axial width of the channel provided by designing one of the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes **314** so that it is gradually sloping from the inlet of the channel towards its outlet.

In **Fig. 26** the divergence of the channel is provided by designing the boundaries confining the channel between them so that the axial width **315** of the channel increases gradually from the inlet **316** of the channel towards its outlet **317**, with the gradual increase in the axial width of the channel provided by designing both of the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes **318,319** so that they are gradually sloping from the inlet of the channel towards its outlet.

In **Fig. 27** the divergence of the channel is provided by designing the boundaries confining the channel between them so that both the axial width **320** of the channel and the width **321** between the opposing parts of the surfaces of the two adjacent vanes confining the channel between them increase gradually from the inlet **322** of the channel towards its outlet **323,** with the gradual increase in the axial width of the channel provided by designing one of the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes **324** so that it is gradually sloping from the inlet of the channel towards its outlet, and with the gradual increase in the width between the opposing parts of the surfaces of the two adjacent vanes provided by designing the vanes with suitable angles of inclination at their different parts, according to the desired angle of divergence of the channel.

In **Fig. 28** the divergence of the channel is provided by designing the boundaries confining the channel between them so that both the axial width **325** of the channel and the width **326** between the opposing parts of the surfaces of the two adjacent vane confining the channel between them increase gradually from the inlet **327** of the channel towards its outlet **328**, with the gradual increase in the axial width of the channel provided by designing both of the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes **329,330** so that they are gradually sloping from the inlet of the channel towards its outlet, and with the gradual increase in the width between the opposing parts of the surfaces of the two adjacent vanes provided by designing the vanes with suitable angles of inclination at their different parts, according to the desired rate of divergence of the channel.

In **Fig. 29** the divergence of the channel is provided by designing the boundaries confining the channel between them so that the width **331** between the opposing parts of the surfaces of the two adjacent vanes confining the channel between them increases gradually from the inlet **332** of the channel towards its outlet **333**, with the gradual increase in the width between the opposing parts of the surfaces of the two adjacent vanes provided by designing the vanes with suitable angles of inclination at their different parts, according to the desired rate of divergence of the channel.

Fig. 30 is a sectional view in a schematic representation of another embodiment of a rotary ram compressor, in accordance with the present invention. The main components of the rotary ram compressor in this embodiment are a stationary casing **351** having an inlet passage **352** for admission of compressible fluid **353** e.g., gas, or vapor, or a mixture of gases and vapors, provided with means for filtering the incoming fluid, and an exit passage **354** for discharge of the pressurized fluid **355**; a drive shaft **356** supported for rotation in a given direction inside the casing by an arrangement of bearings **357**, and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes a disk **358**, and a plurality of vanes **359** arranged circumferentially within the annular space defined in-between the relatively inner surface of the disk and its opposing inner surface of the casing. The disk is secured for rotation about the drive shaft. Each of the circumferentially arranged vanes has a first edge **362** attached to the inner surface of the disk, a second free edge **363,** a relatively radially outwards leading edge or tip, and a relatively radially inward trailing edge or tail (not shown in the drawing), with the design and operation of the circumferentially arranged vanes being quite similar to those of the embodiment of **Figs. 4, 5**, noting that the inner surface of the disk forming part of the boundaries of the channels confined in-between the vanes **364** is sloped. The clearance space between the free edges of the vanes and the casing is kept at a minimum to decrease the flow of pressurized gases round the free edges of the vanes, and thus minimize the associated decrease in the overall machine efficiency.

Fig. 31 is a sectional view in a schematic representation of an exemplary embodiment of another rotary ram pump, in accordance with the present invention, wherein the provided pressurized fluid is discharged through a propelling nozzle. The main components of the rotary ram compressor in this embodiment are a stationary casing **371** having an inlet passage **372** for admission of an incompressible fluid, i.e., liquid **373**, and an exit passage **374** for discharge of the pressurized fluid **375**, and a convergent nozzle **376** freely communicating with the exit passage; a drive shaft **377** supported for rotation in a given direction inside the casing by an arrangement of bearings **378**, and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes a disk **359**, and a plurality of vanes arranged circumferentially in two axially stacked levels **380,381**, a first level **380** within the annular spaces defined in-between one of the surfaces of the disk and its opposing inner surface of the casing, and a second level **381** within the annular space defined in-between the other surface of the disk and the casing. The disk is secured for rotation about the drive shaft. Each of the vanes of each level has a first edge **382, 383** attached to their related inner surface of the disk, a second free edge **384,385,** a relatively radially outwards leading edge or tip, and a relatively radially inward trailing edge or tail (not shown in the drawing), with the design and operation of the circumferentially arranged vanes being quite similar to those of the embodiment of **Figs. 7, 8.** The clearance space between the free edges of the vanes and the casing is kept at a minimum to decrease the flow of pressurized gases round the free edges of the vanes, and thus minimize the associated decrease in the overall machine efficiency.

Fig. 32 is a sectional view in a schematic representation of an exemplary embodiment of another rotary ram pump, in accordance with the present invention. The main components of the rotary ram pump in this embodiment are a stationary casing **391** having an inlet passage **392** for admission of fluid **393,** and a volute chamber **394** communicating with an exit passage **395** for discharge of the pressurized fluid **396;** a drive shaft **397** supported for rotation in a given direction inside the casing by an arrangement of bearings **398**, and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes a disk **399**, and a plurality of vanes **400** arranged circumferentially within the annular space defined in-between the relatively inner surface of the disk and its opposing inner surface of the casing. The disk is secured for rotation about the drive shaft. Each of the circumferentially arranged vanes has a first edge **401** attached to the inner surface of the disk, a second free edge **402,** a relatively radially inward leading edge or tip, and a relatively radially outward trailing edge or tail (not shown in the drawing), with the design and operation of the circumferentially arranged vanes being quite similar to those of the embodiment of **figs. 11, 12.** The clearance space between the free edges of the vanes and the casing is kept at a minimum to decrease the flow of pressurized gases round the free edges of the vanes, and thus minimize the associated decrease in the overall machine efficiency.

Fig. 33 is a sectional view in a schematic representation of an exemplary embodiment of another rotary ram compressor, in accordance with the present invention. The main components of the rotary ram compressor in this embodiment are a stationary casing **411** having an inlet passage **412** for admission of compressible fluid **413,** and an exit passage **414** for discharge of the pressurized fluid **415;** a drive shaft **416** supported for rotation in a given direction inside the casing by an arrangement of bearings **417**, and extending to a drive receiving end located outside the casing; and a rotor assembly housed inside the casing. The rotor assembly includes a disk **418**, and a plurality of vanes arranged in two concentric sets **419,420,** within the annular space defined in-between the relatively inner surface of the disk and its opposing inner surface of the casing. The disk is secured for rotation with the drive shaft. Each of the vanes has a first edge **421, 422** attached to the inner surface of the disk, a second free edge **423,424,** a relatively radially inwards leading edge or tip, and a relatively radially outward trailing edge or tail (not shown in the drawing), with the design and operation of the circumferentially arranged vanes being quite similar to those of the embodiment of **figs. 13, 14.** The clearance space between the free edges of the vanes and the casing is kept at a minimum to decrease the flow of pressurized gases round the free edges of the vanes, and thus minimize the associated decrease in the overall machine efficiency.

Fig. 34 illustrates one of the practical ranges within which the angles of inclination of the vanes of the rotor of a rotary ram fluid pressurizing machine may be designed, according to the present invention and illustrates the meaning of the term *angle of inclination* as used herein.

The vane is preferably smoothly curved from its leading edge $\mathbf{l}_1$ towards its trailing edge $\mathbf{t}_1$. The angle of inclination of the successive portions of the vane are measured with respect to a plane $\mathbf{x}$-$_1$-$\mathbf{x}_1$ comprising the midpoint of the vane $\mathbf{m}_1$ and perpendicular to a radial plane $\mathbf{c}_1$-$\mathbf{m}_1$ including the rotational axis $\mathbf{c}_1$ of the rotor and the midpoint $\mathbf{m}_1$ of the vane. In this illustrative embodiment, the angle of inclination $\mathbf{a}_1$ at the leading edge of the vane $\mathbf{l}_1$ is + 15 degrees, and is gradually decreasing towards the trailing edge $\mathbf{t}_1$ wherein the angle of inclination $\mathbf{b}_1$ is - 43 degrees. And thus, the used range of angles of inclination in this embodiment is from + 15 to - 43 degrees.

Fig. 35 illustrates another practical range within which the angles of inclination of the vanes of the rotor of another rotary ram fluid pressurizing machine may be designed, according to the present invention.

The vane is preferably smoothly curved from its leading edge $\mathbf{l}_2$ towards its trailing edge $\mathbf{t}_2$. The angle of inclination of the successive portions of the vane are measured with respect to a plane $\mathbf{x}_2$-$\mathbf{x}_2$ comprising the midpoint of the vane $\mathbf{m}_2$ and perpendicular to a radial plane $\mathbf{c}_2$-$\mathbf{m}_2$ including the rotational axis $\mathbf{c}_2$ of the rotor and the midpoint $\mathbf{m}_2$ of the vane. In this illustrative embodiment, the angle of inclination $\mathbf{a}_2$ at the leading edge of the vane $\mathbf{L}_2$ is + 44 degrees, and is gradually decreasing towards the trailing edge $\mathbf{t}_2$ wherein the angle of inclination $\mathbf{b}_2$ is - 16 degrees. And thus, the used range of angles of inclination in this embodiment is from + 44 to - 16 degrees.

It should be appreciated that the inlet and outlet of each of the diverging channels formed by two adjacent vanes together with the related surfaces of two adjoining disks or of a disk and the casing are radially opposed to each other. By this it is meant that each inlet is disposed at a smaller radial distance from the drive shaft than its corresponding outlet, or that each outlet is disposed at a smaller radial distance from the drive shaft than the corresponding inlet as appropriate when the rotary ram fluid pressurizing machine is used respectively to displace fluid generally radially outwards or generally radially inwards. However, it should be appreciated that prior art pumps or fans comprising disks with straight vanes disposed radially and thereby ostensibly having passages with radially opposed inlets and outlets do not suggest the present invention since such devices fail to provide curved diverging channels and fail to utilize the rotary ramming technique herein disclosed. Further it should be understood that a particular embodiment of a rotary ram fluid pressuring machine may comprise disks having vanes disposed to produce both radially inward displacement of fluid and radially outward displacement of fluid to achieve a desired net result.

Further objectives and advantages of the present invention will be apparent to those skilled in the art from the detailed description of the disclosed invention. The present discussion of illustrative embodiments is not intended to limit the spirit and scope of the invention beyond that specified by the claims presented hereafter.

What is claimed is:

1. A rotary ram fluid pressurizing machine comprising:

a stationary casing having an inlet passage for admission of fluid, and at least one exit passage for discharge of pressurized fluid;

a drive shaft supported for rotation in the casing by an arrangement of bearings and extending to a drive receiving end located outside the casing; and

a rotor assembly housed inside the casing and including a plurality of axially spaced disks surrounding the drive shaft and lying in planes transverse to the rotational axis of the drive shaft, at least one disk being secured for rotation about the drive shaft, at least two disks defining an annular space in-between with a plurality of vanes arranged circumferentially within the annular space between the two disks, each vane attached to at least one of the two disks defining the annular space, each vane having a leading edge, a trailing edge, a concave surface and a convex surface, the opposing parts of the surfaces of each two adjacent vanes along with the opposing parts of the two disks' surfaces confined between the opposing parts of the surfaces of each two adjacent vanes defining a channel between each two adjacent vanes, each channel having an inlet and an outlet, each inlet and each outlet communicating with radially opposed spaces within the annular space, the cross-sectional area of each channel increasing from the channel inlet to the channel outlet.

2. The machine of claim 1, wherein each vane is smoothly curved from the leading edge

to the trailing edge, the angles of inclination of successive portions of each vane decreasing gradually from the leading edge to the trailing edge.

3. The machine of claim 1, wherein the angles of inclination range from about +26 to about -48 degrees.

4. The machine of claim 1, wherein the angles of inclination range from about +56 to about -20 degrees.

5. The machine of claim 1, wherein the width between the opposing parts of the surfaces of the two adjacent vanes defining the channel between them increases gradually from the inlet of the channel to the outlet of the channel.

6. The machine of claim 1, wherein at least one of the opposing parts of the disks' surfaces related to a channel and confined between the opposing parts of the surfaces of the two adjacent vanes, is sloping such that the axial width of the channel increases gradually from the inlet of the channel towards the outlet.of the channel.

7. The machine of claim 1, wherein at least one of the opposing parts of the disks' surfaces related to a channel and confined between the opposing parts of the surfaces of the two adjacent vanes, is sloping such that the axial width of the channel increases gradually from the inlet of the channel towards the outlet of the channel, and wherein

the width between the opposing parts of the surfaces of the two adjacent vanes defining the channel between them increases gradually from the inlet of the channel towards the outlet of the channel.

8. The machine of claim 1 wherein the plurality of vanes arranged circumferentially within the annular space between the two disks are arranged into a plurality of concentric sets of annularly disposed vanes.

9. The machine of claim 1 wherein the plurality of axially spaced disks is at least three disks forming at least two axially stacked annular spaces, each stacked annular space having a plurality of vanes arranged circumferentially within.

10. The machine of claim 9 wherein the plurality of vanes arranged circumferentially within each stacked annular space are arranged into a plurality of concentric sets of annularly disposed vanes.

11. The machine of claim 1 wherein the at least one exit passage is at least two exit passages, the exit passages being separated by an intermediate septum, each exit passage having at least one exit port, the drive shaft being axially movable so that pressurized fluid may be directed to a selected exit port by axial displacement of the drive shaft.

12. The machine of claim 11 wherein the plurality of vanes arranged circumferentially within the annular space between the two disks are arranged into a plurality of concentric sets of annularly disposed vanes.

13. The machine of claim 11 wherein the plurality of axially spaced disks is at least three disks forming at least two axially stacked annular spaces, each stacked annular space having a plurality of vanes arranged circumferentially within.

14. A rotary ram fluid pressurizing machine comprising

a stationary casing having at least one inlet passage for admission of fluid, and at least one exit passage for discharge of pressurized fluid;

a first shaft having a first support for rotation in the casing extending to a drive receiving end located outside the casing;

a second shaft concentric with the first shaft, the second shaft having a second support for rotation in the casing, at least one of the first shaft and the second shaft being axially movable; and

a rotor assembly located inside the casing including a first disk surrounding the first shaft and lying in a first plane transverse to the rotational axis of the first shaft, a second disk surrounding the second shaft and lying in a second plane transverse to the rotational axis of the second shaft and axially spaced from the first plane, the first disk secured for rotation about the first shaft, the second disk secured for rotation about the second shaft, each of the two disks having a relatively outer surface facing its adjacent part of the casing and a relatively inner surface, the inner surfaces of the two disks defining an annular space in-between, and a plurality of vanes arranged circumferentially within the annular space, each of the vanes having a first edge attached to the inner surface of one of the two disks, a second edge forming a male end in fluid tight communication with a female groove in the inner surface of the other disk, each vane having a leading edge, a trailing edge, a concave surface and a convex surface, the opposing parts of the surfaces of each two adjacent vanes defining a channel between them, the channel confined by a part of the concave surface of one vane and the opposing part of the convex surface of an adjacent vane, the boundaries of the channel formed of the opposing parts of the surfaces of the two adjacent vanes and the opposing parts of the disks' surfaces related to the channel and confined between the opposing parts of the surfaces of the two adjacent vanes, each channel having an inlet and an outlet, each inlet and each outlet communicating with radially opposed spaces within the annular space, the cross-sectional area of each channel gradually increasing from its inlet towards its outlet.

15. The machine of claim 14 wherein the plurality of vanes arranged circumferentially within the annular space between the two disks are arranged into a plurality of concentric sets of annularly disposed vanes.

16. The machine of claim 14 wherein the at least one exit passage is at least two exit passages, the exit passages being separated by an intermediate septum, each exit passage having at least one exit port, and wherein the first shaft and the second shaft are axially movable so that pressurized fluid may be directed to a selected exit port by

axial displacement of the first shaft and the second shaft.

17. A rotary ram fluid pressurizing machine comprising:

a stationary casing having an inlet passage for admission of fluid, and at least one exit passage for discharge of pressurized fluid;

a drive shaft supported for rotation in the casing by an arrangement of bearings and extending to a drive receiving end located outside the casing;

a rotor assembly housed inside the casing and including

at least one rotatable disk surrounding the drive shaft and lying in a plane transverse to the rotational axis of the drive shaft and being secured for rotation about the drive shaft;

at least one fixed surface fixedly attached to the casing; and

a plurality of vanes arranged circumferentially within at least one annular space between at least one of the surfaces of at least one rotatable disk and an adjacent at least one fixed surface, each vane having a first edge and a second edge, the first edge being attached to a surface of the at least one rotatable disk, the second edge being in substantially fluid tight contact with the adjacent at least one fixed surface, each vane having a leading edge, a trailing edge, a concave surface and a convex surface, the opposing parts of the surfaces of each two adjacent vanes along with the parts of the first surface of the at least one rotatable disk and the at least one fixed surface confined between the opposing parts of the surfaces of each two adjacent vanes defining a channel between each two adjacent vanes, each channel having an inlet and an outlet, each inlet and each outlet communicating with radially opposed spaces within the annular space, the cross-sectional area of each channel increasing from the channel inlet to the channel outlet.

18. The machine of claim 17 wherein the interior surface of the casing comprises one of the at least one fixed surface.

19. The machine of claim 17 wherein the plurality of vanes arranged circumferentially within the at least one annular space are arranged into a plurality of concentric sets of annularly disposed vanes.

20. The machine of claim 17 wherein the at least one fixed surface is at least two fixed surfaces on a disk fixedly attached to the casing and coaxial with the at least one rotatable disk.

21. The machine of claim 20 wherein the at least one rotatable disk is two rotatable disks coaxial with the disk fixedly attached to the casing, the disk fixedly attached being disposed between the two rotatable disks and forming two annular spaces, one annular space being between each rotatable disk and the disk fixedly attached to the casing.

22. The machine of claim 20, wherein each vane is smoothly curved from the leading edge to the trailing edge, the angles of inclination of successive portions of each vane decreasing gradually from the leading edge to the trailing edge.

23. The machine of claim 20, wherein the angles of inclination range from about +26 to about -48 degrees.

24. The machine of claim 20, wherein the angles of inclination range from about +56 to about -20 degrees.

25. The machine of claim 20, wherein the width between the opposing parts of the surfaces of the two adjacent vanes defining the channel between them increases gradually from the inlet of the channel to the outlet of the channel.

26. The machine of claim 20, wherein the part of the surface of the at least one rotatable disk confined between the opposing parts of the surfaces of the two adjacent vanes is sloping such that the axial width of the channel increases gradually from the inlet of the channel towards the outlet.of the channel.

27. The machine of claim 20, wherein the part of the surface of the at least one rotatable disk confined between the opposing parts of the surfaces of the two adjacent vanes is sloping such that the axial width of the channel increases gradually from the inlet of the channel towards the outlet of the channel, and wherein the width between the opposing parts of the surfaces of the two adjacent vanes defining the channel between them increases gradually from the inlet of the channel towards the outlet of the

channel.

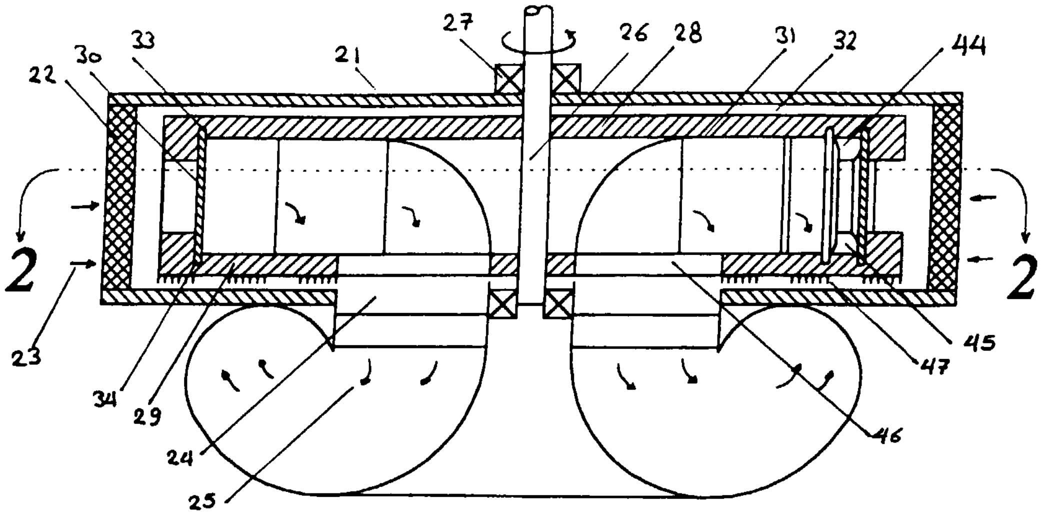

FIG.1

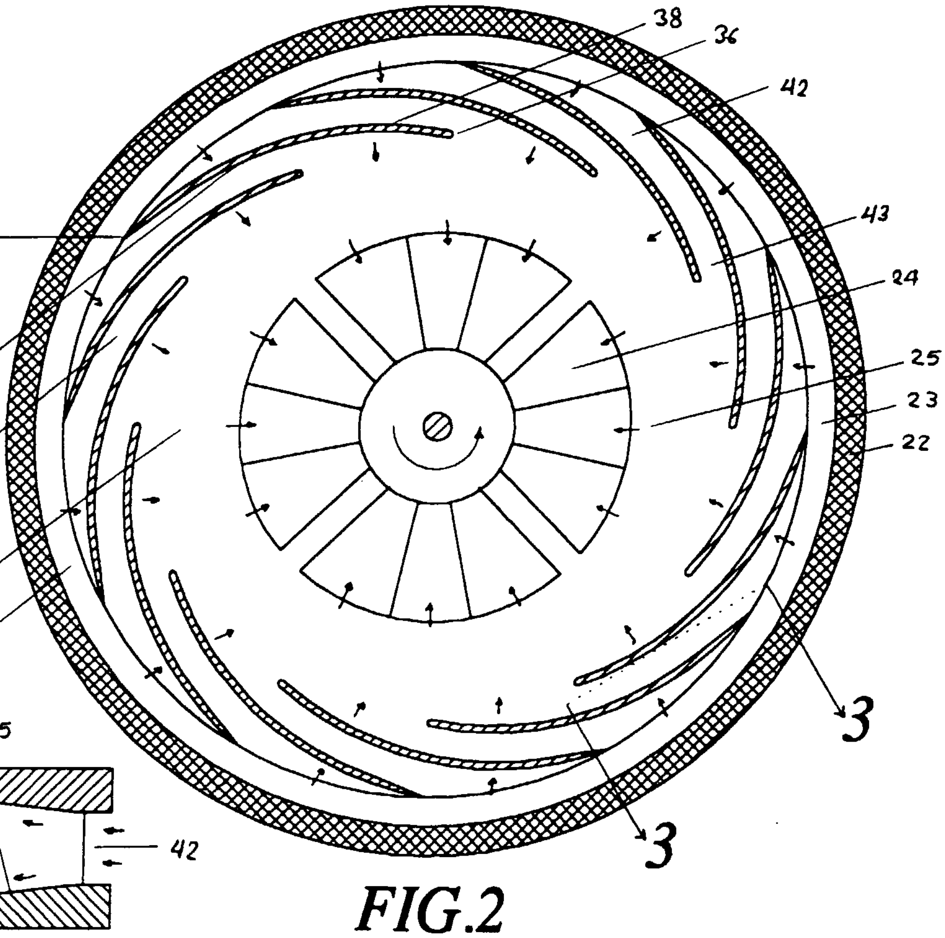

FIG.2

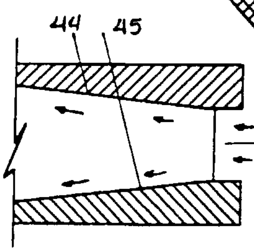

FIG.3

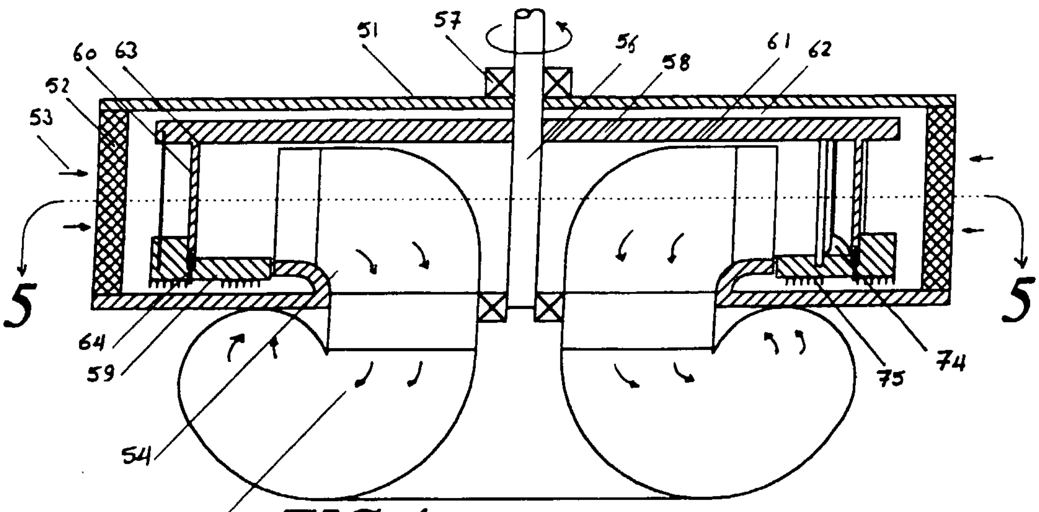

FIG.4

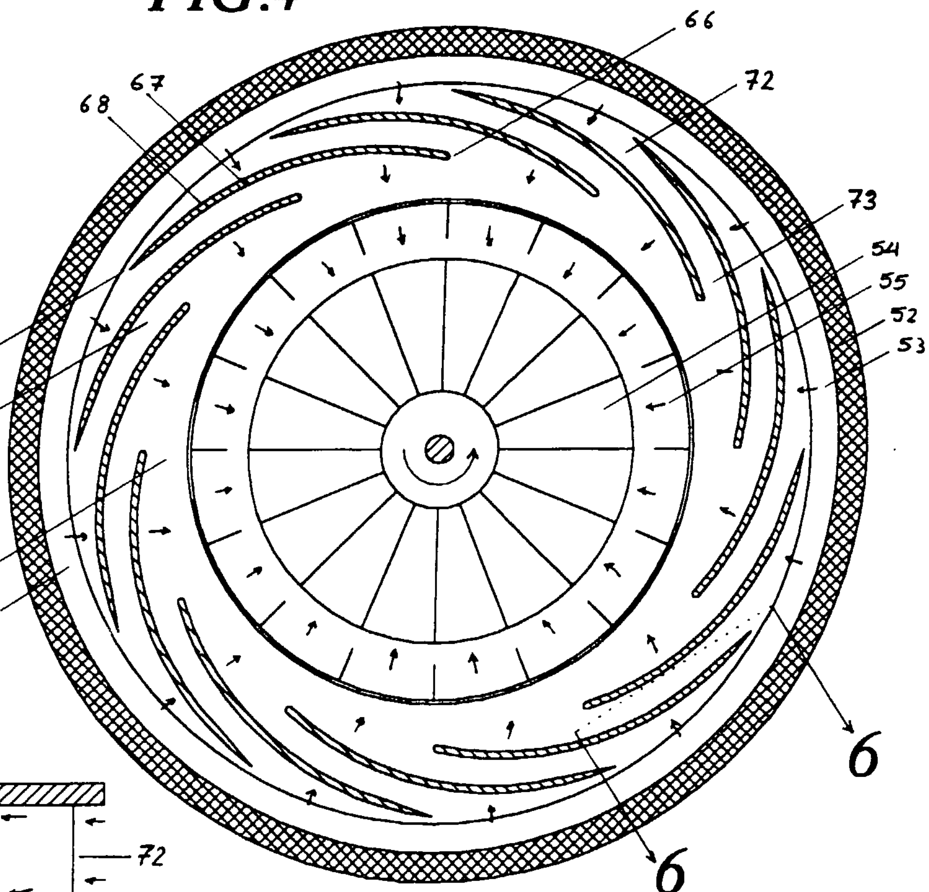

FIG.5

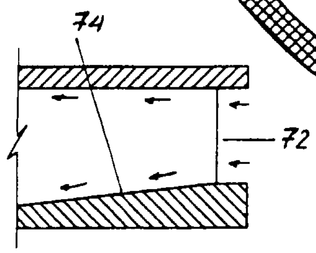

FIG.6

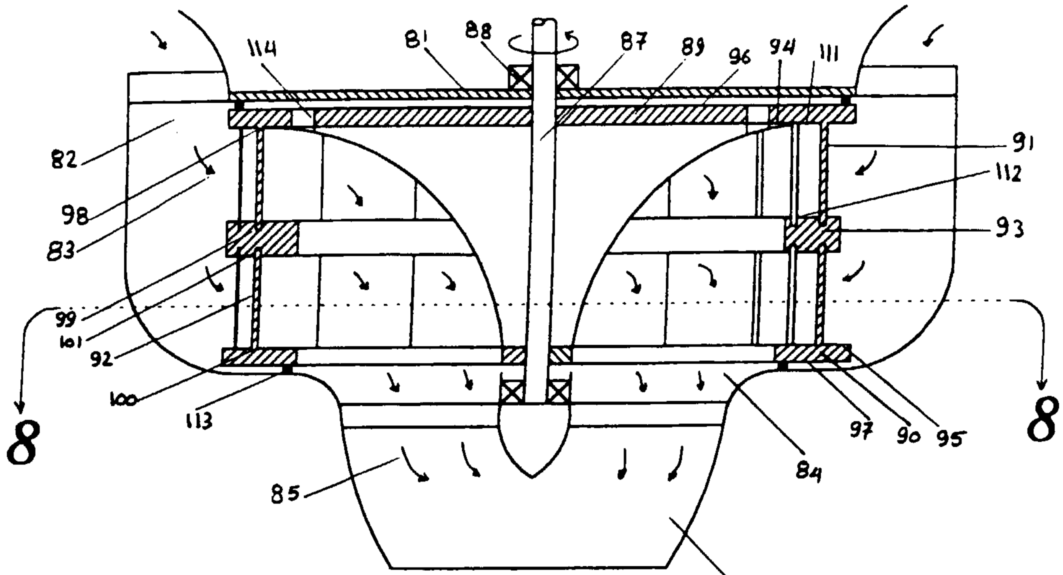
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FIG.7

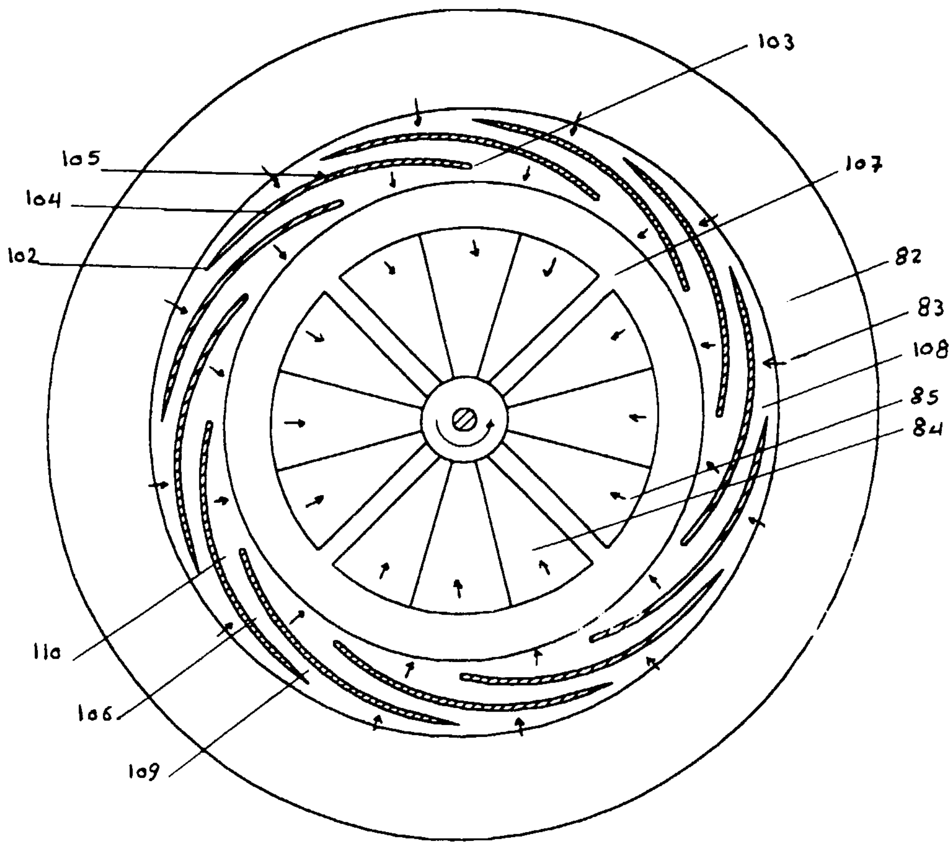
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FIG.8

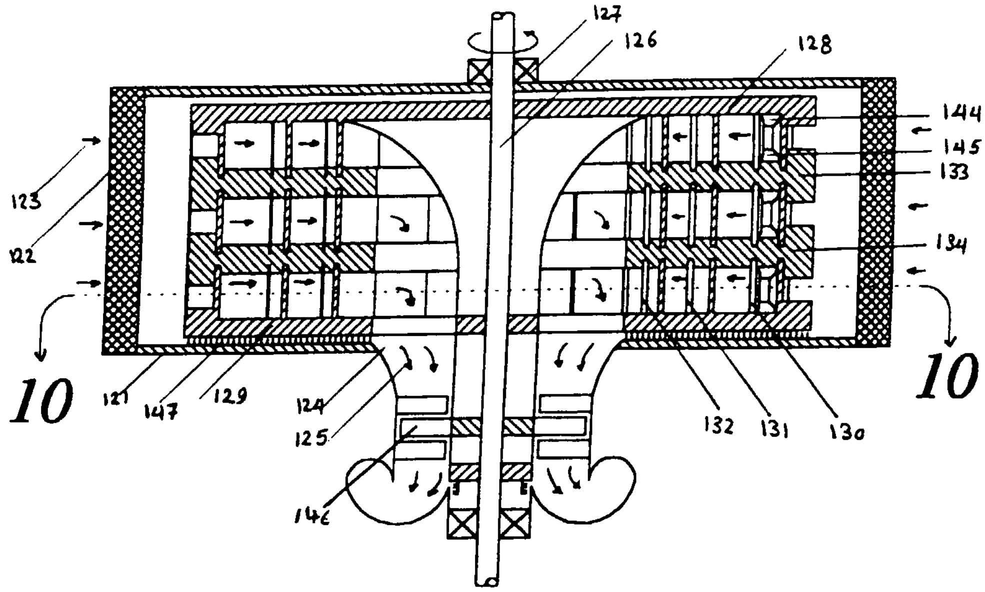
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FIG.9

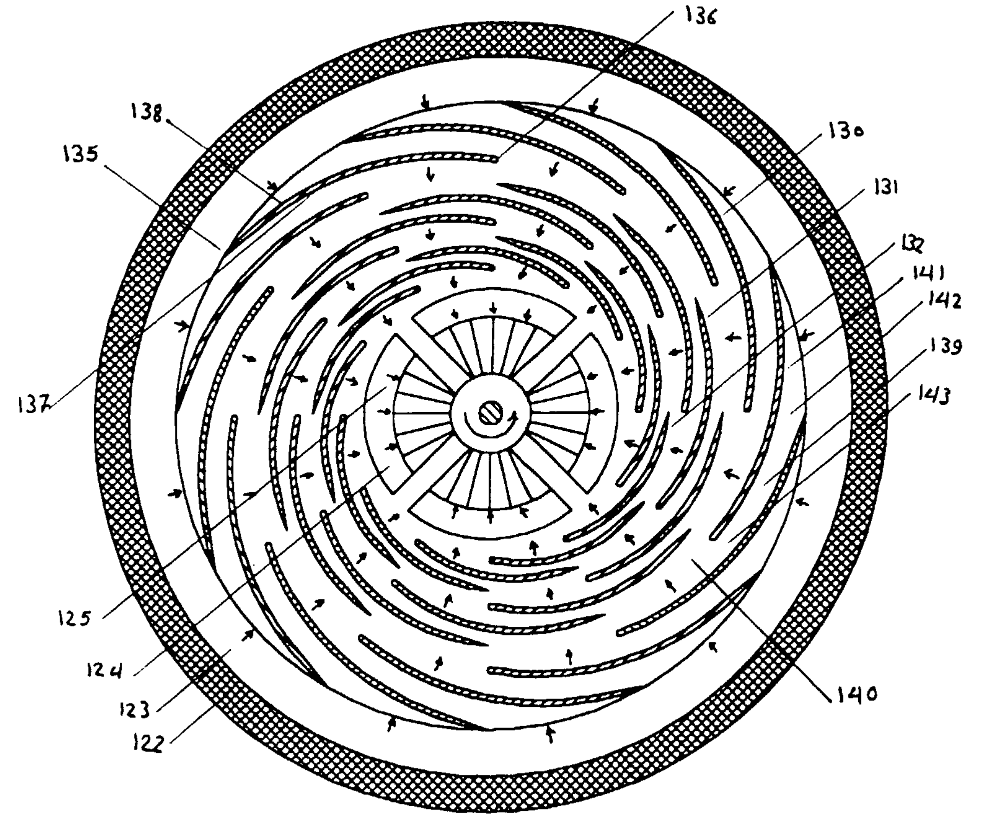
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FIG.10

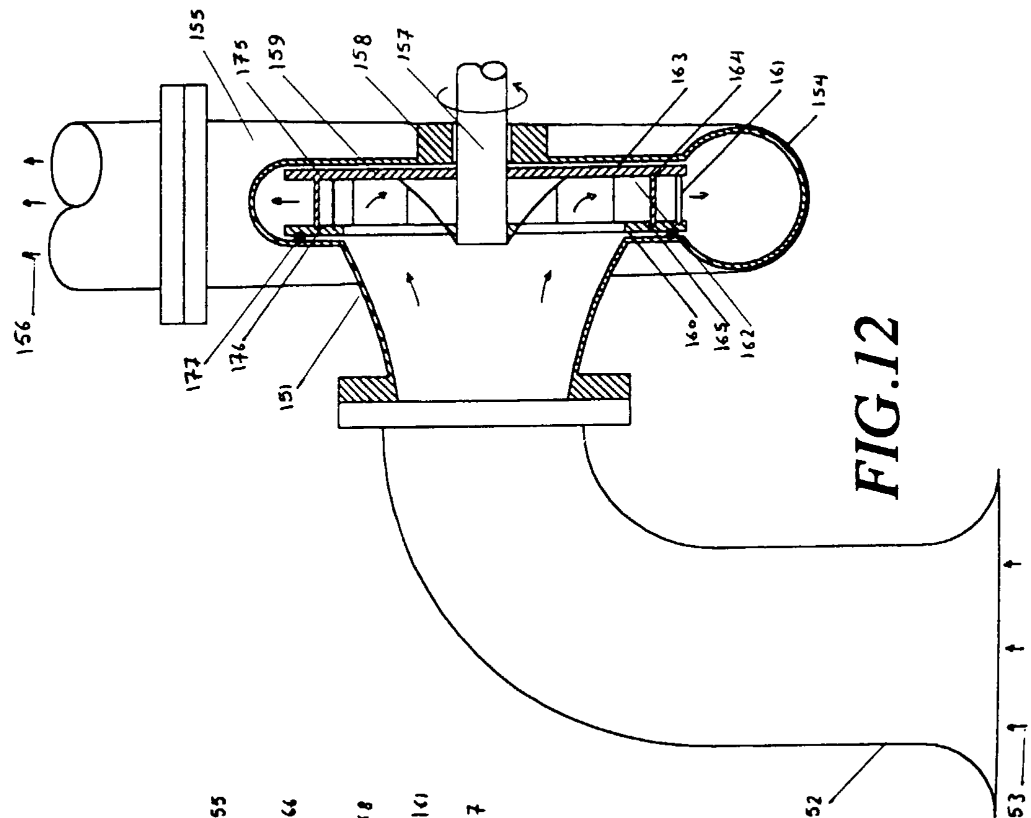
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FIG.12

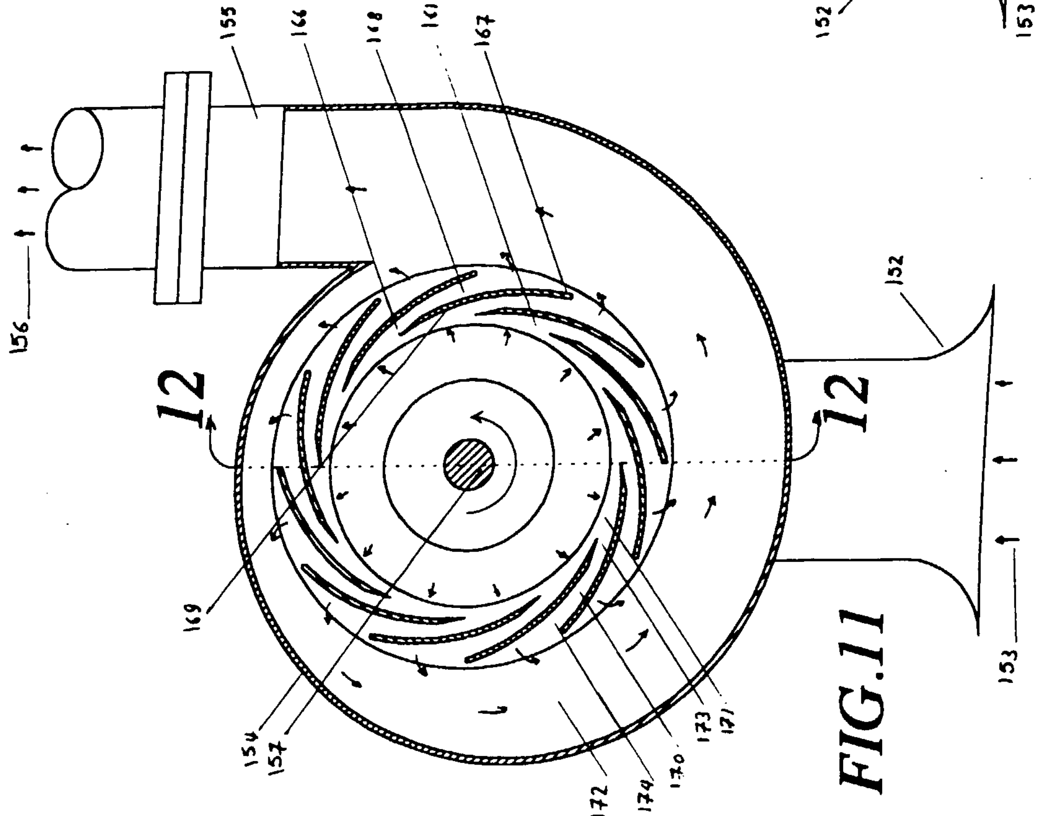
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FIG.11

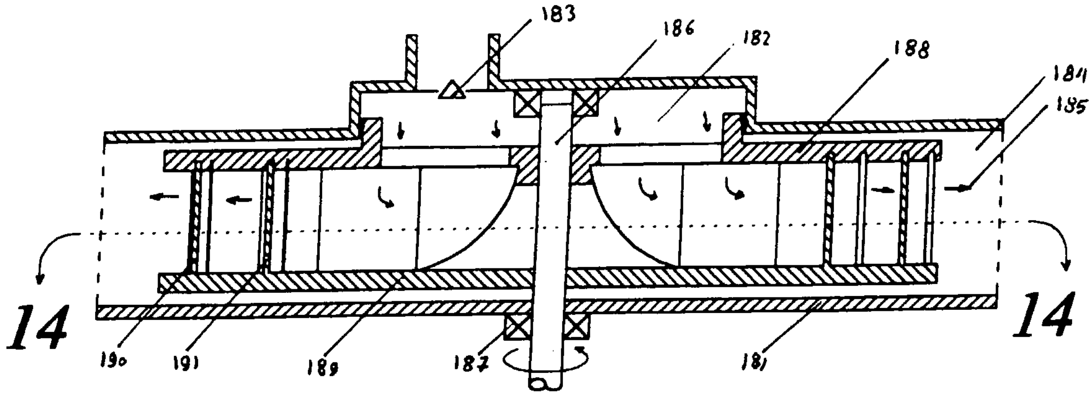
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FIG.13

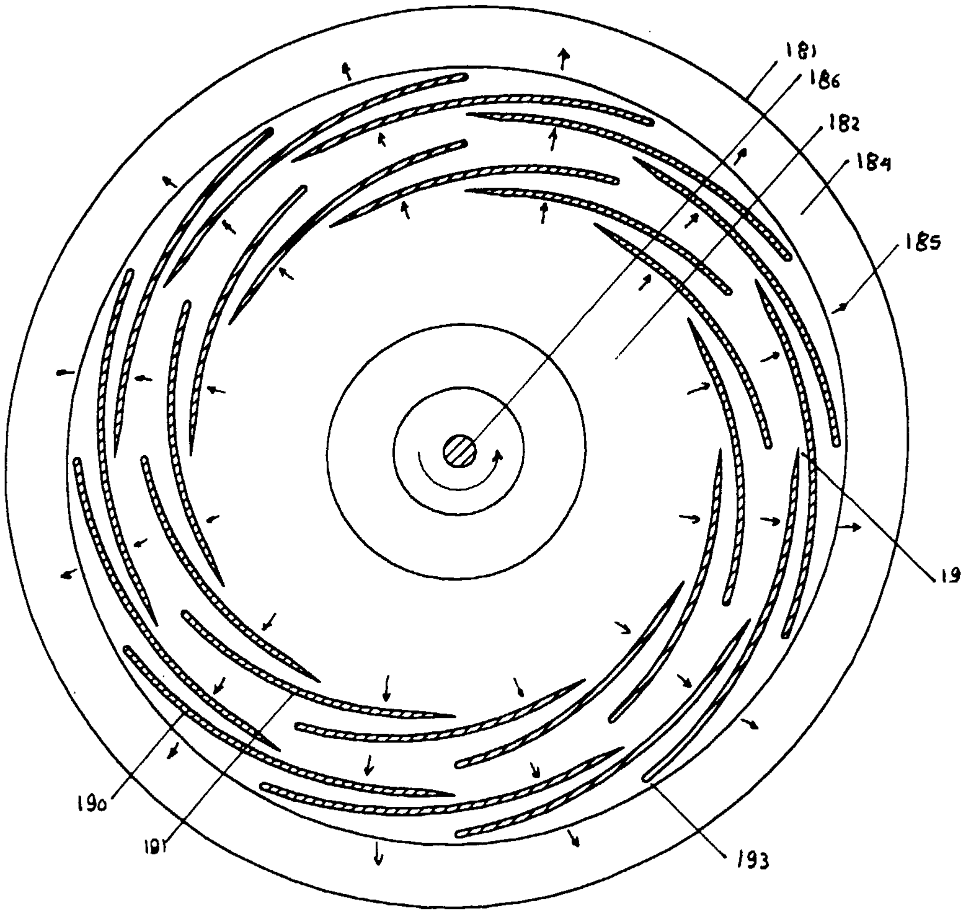
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FIG.14

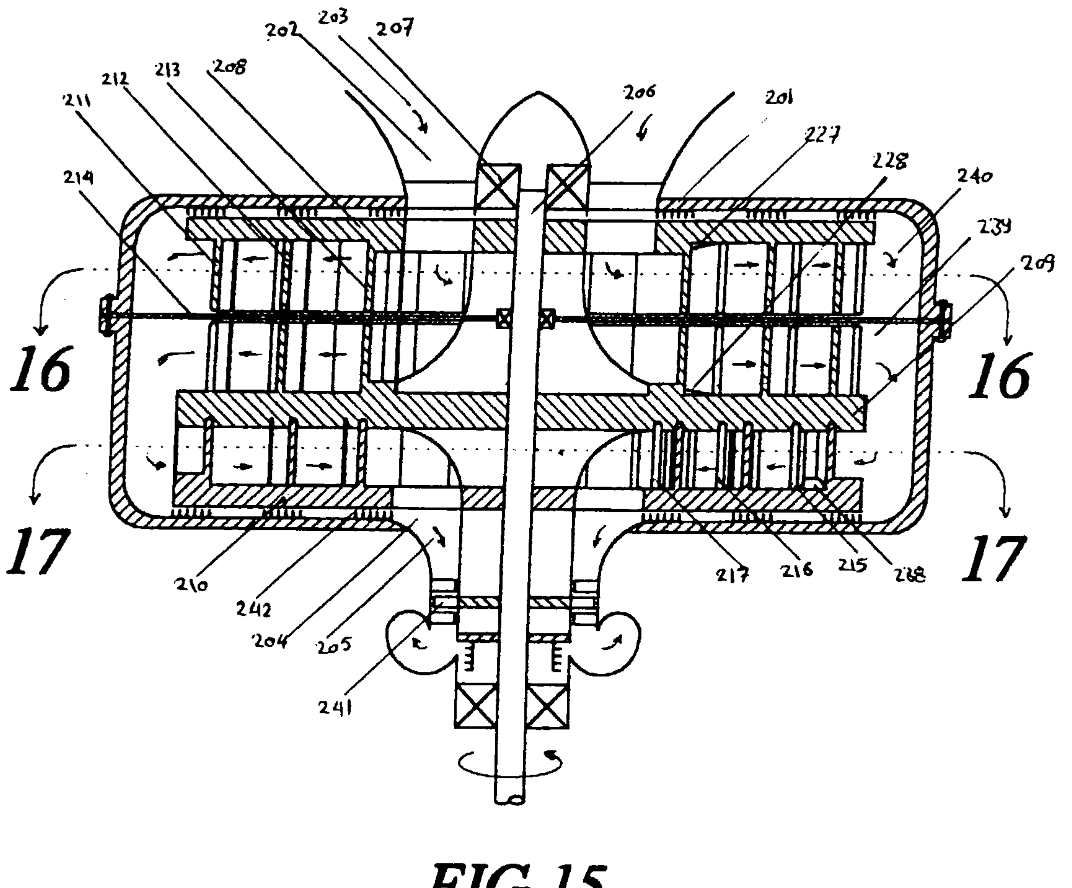
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FIG.15

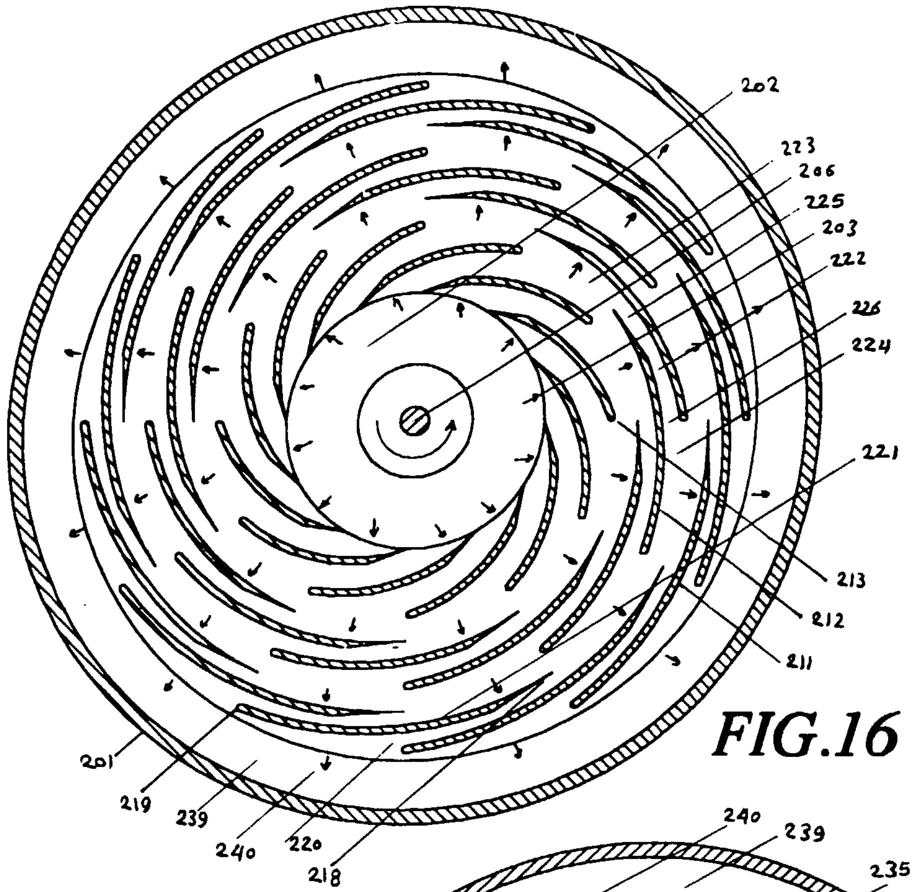
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FIG.16

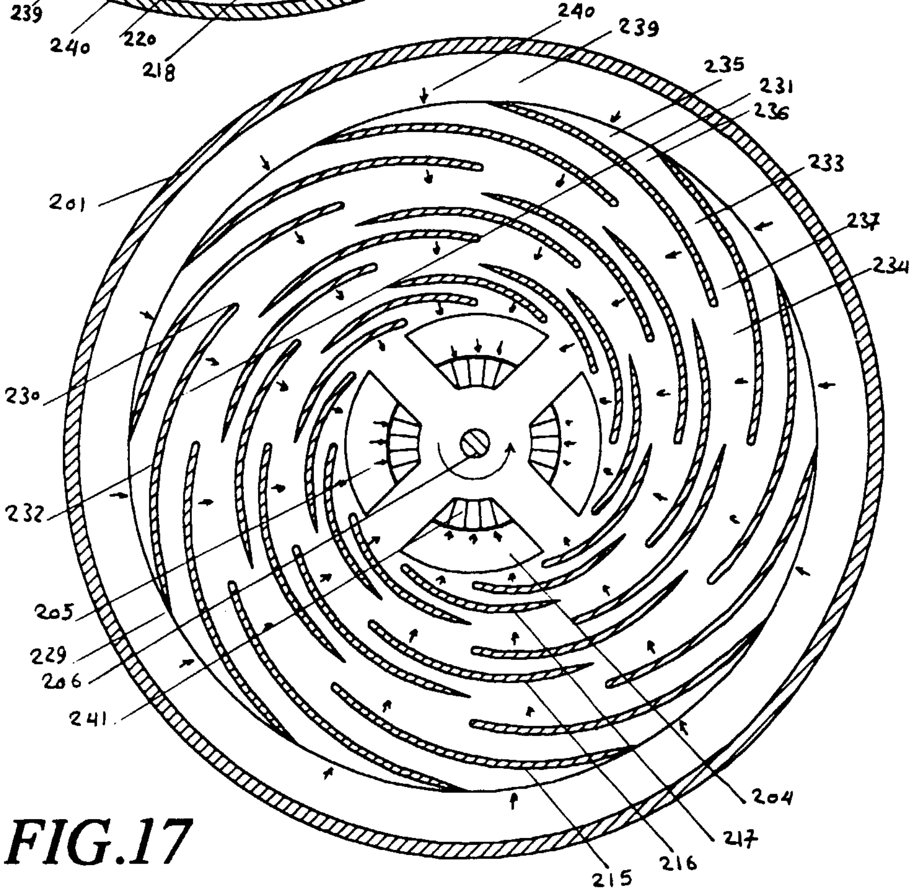
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FIG.17

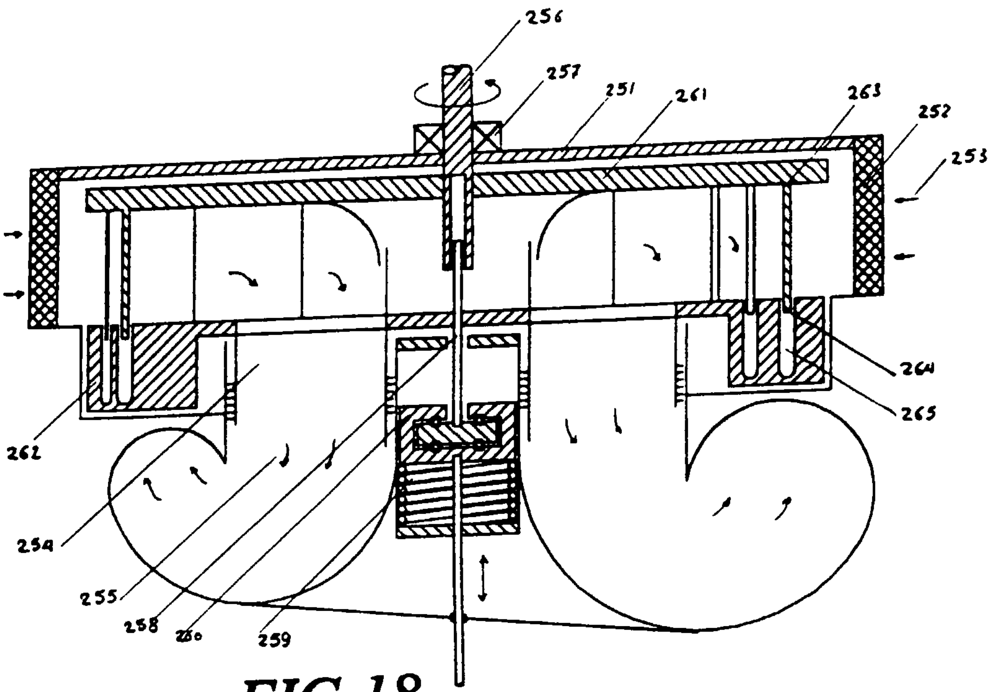
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FIG.18

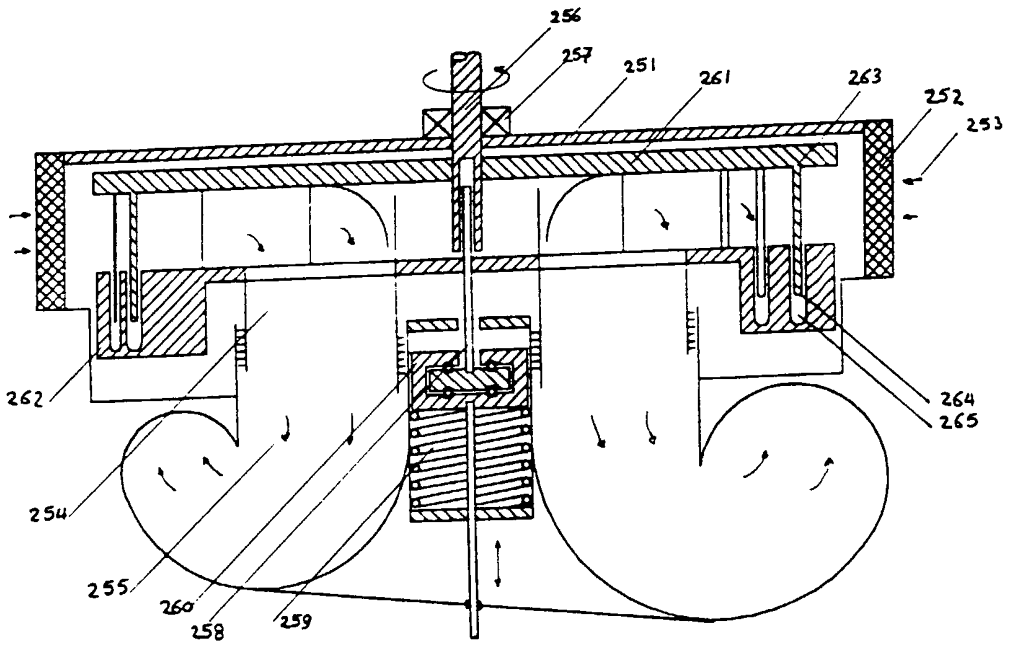
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FIG.19

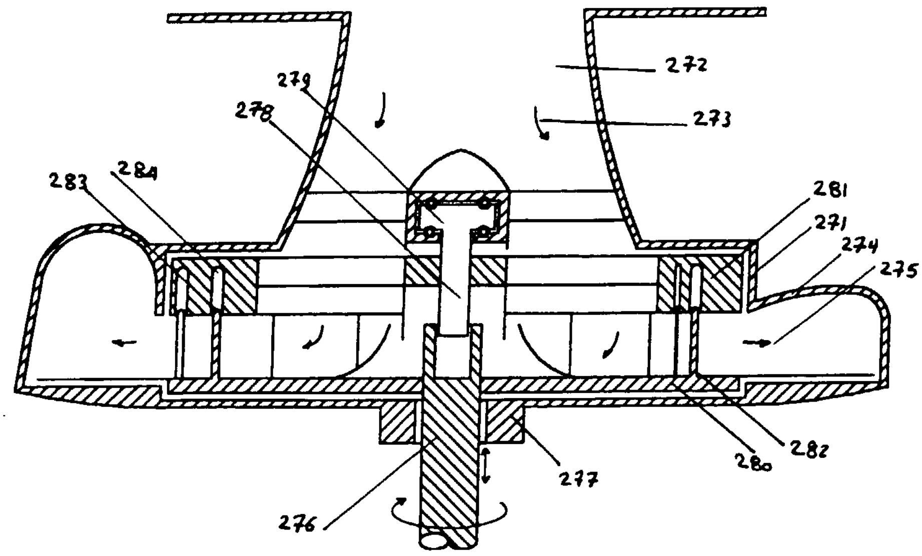
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FIG.20

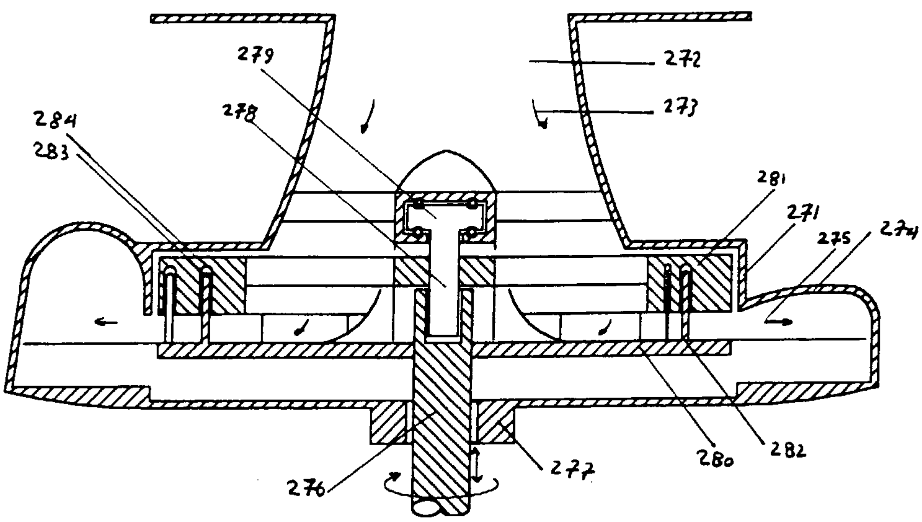
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FIG.21

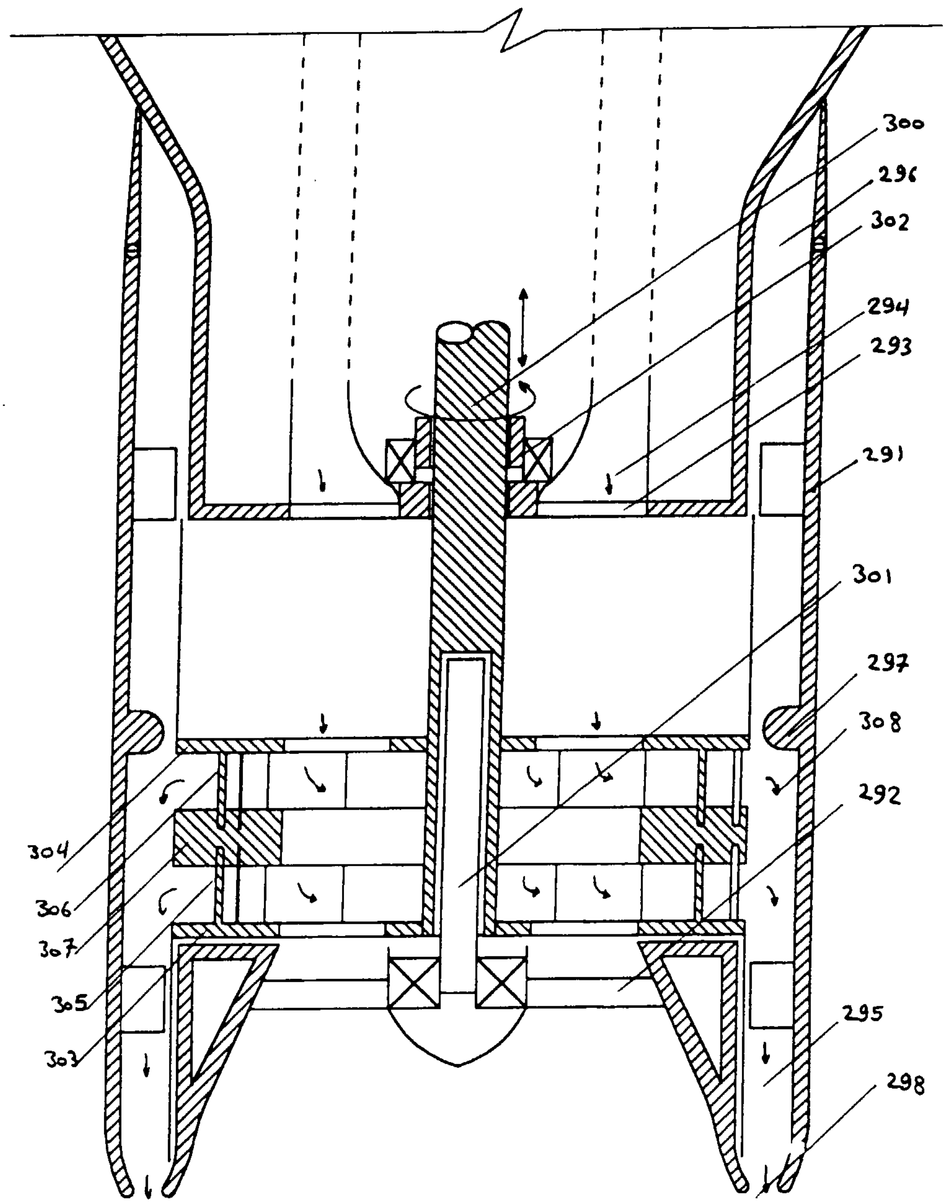
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FIG.22

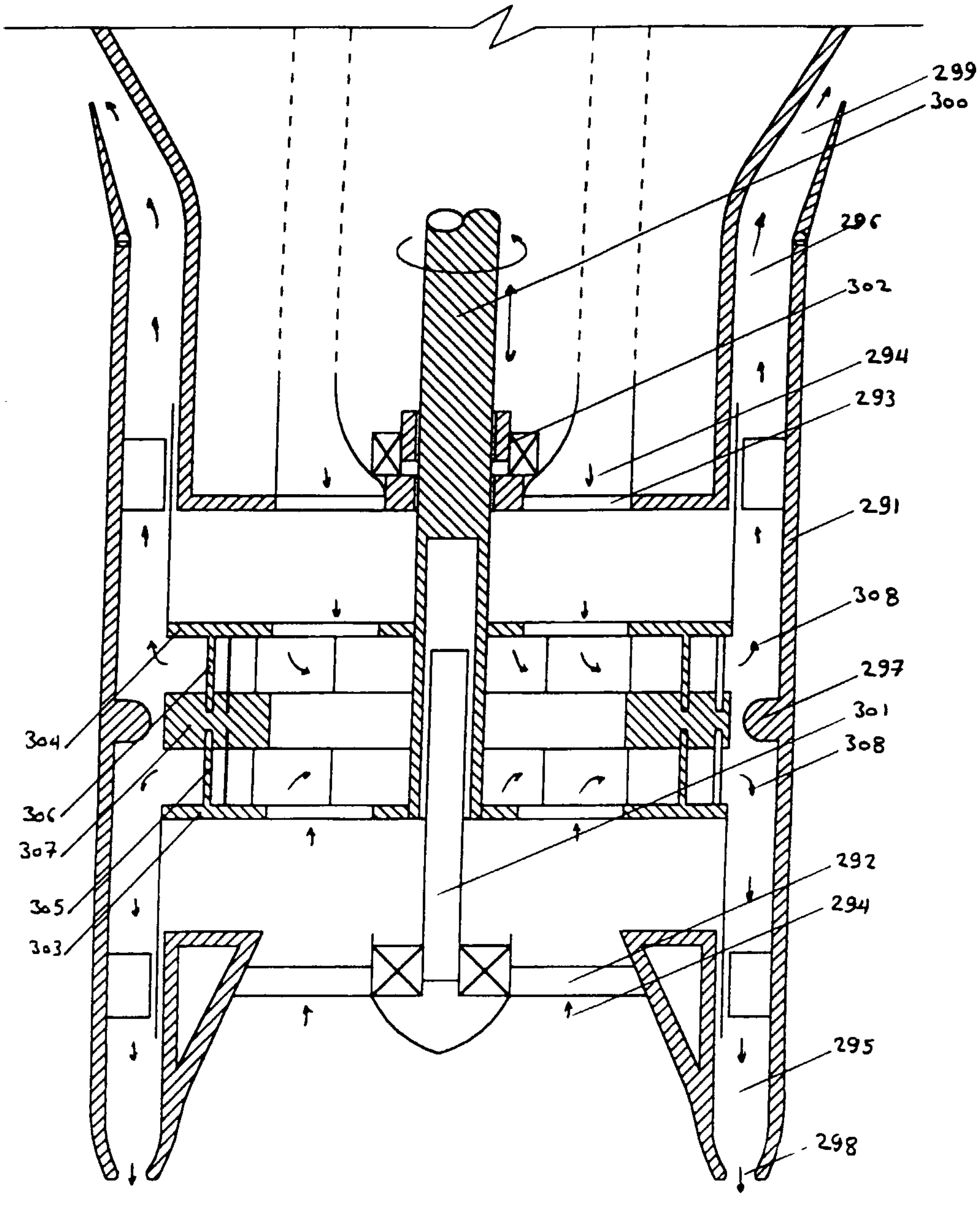
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FIG.23

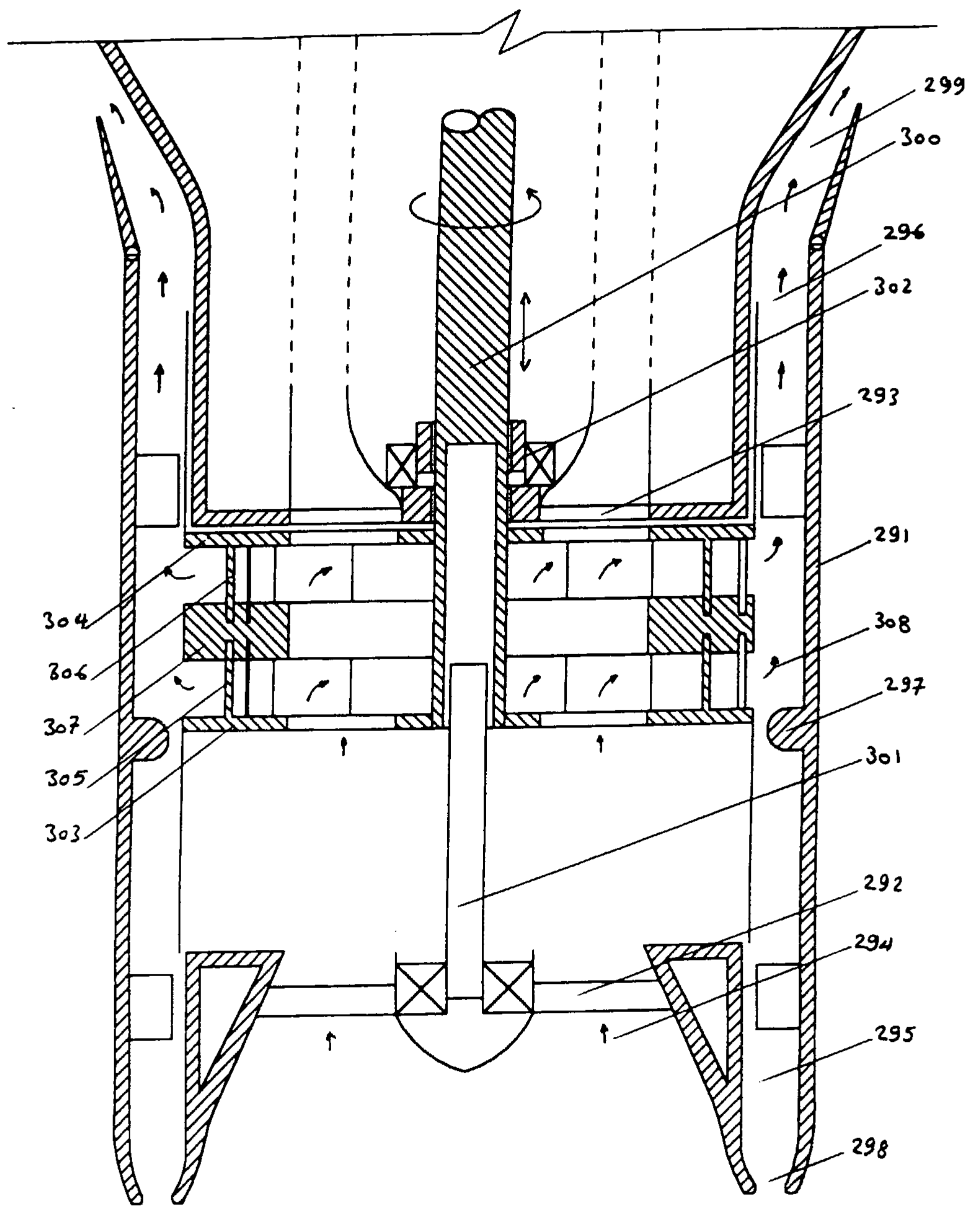
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FIG.24

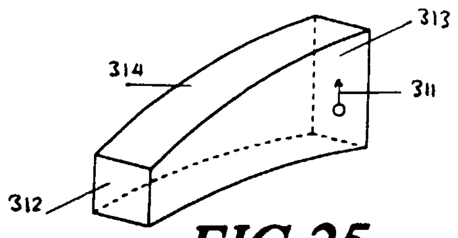

FIG.25

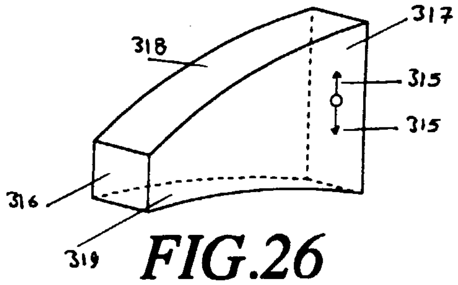

FIG.26

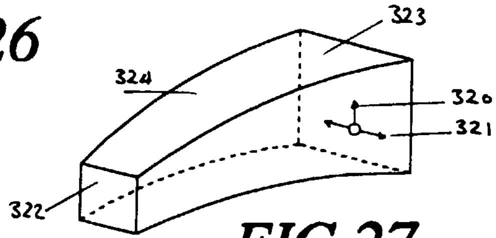

FIG.27

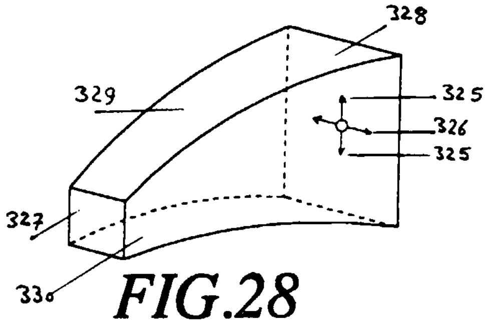

FIG.28

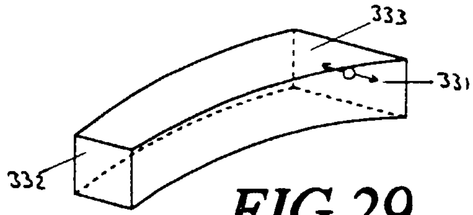

FIG.29

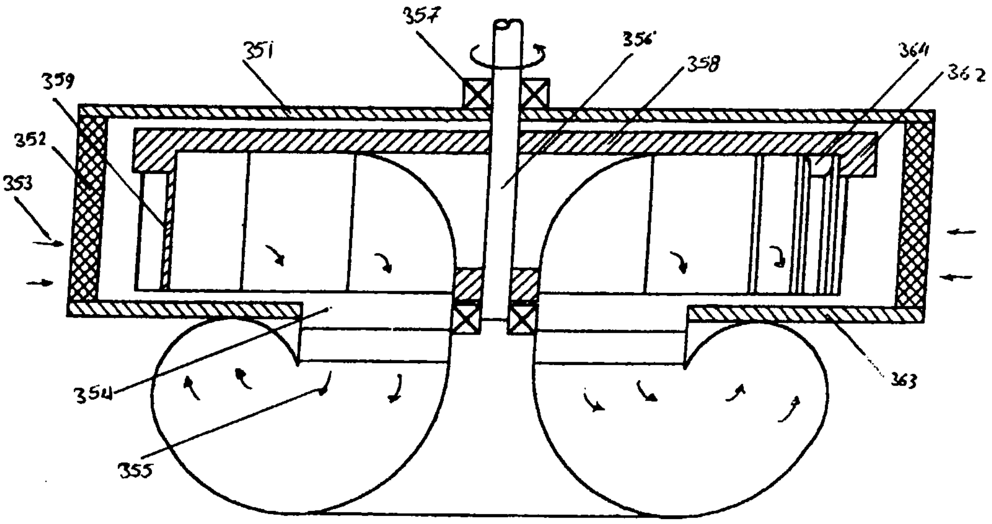
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FIG.30

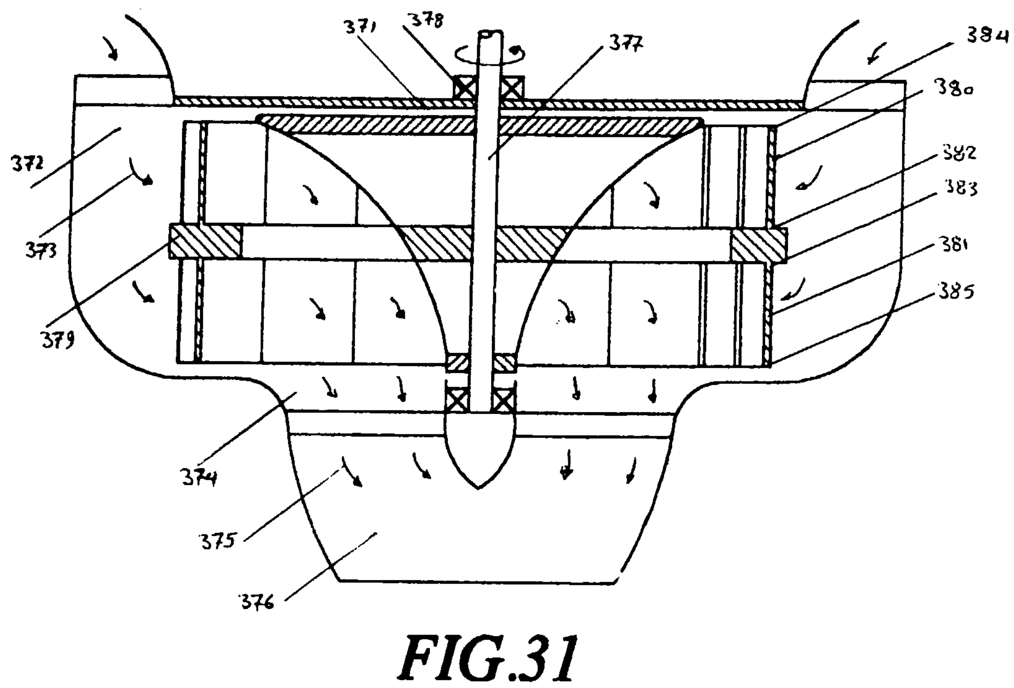
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FIG.31

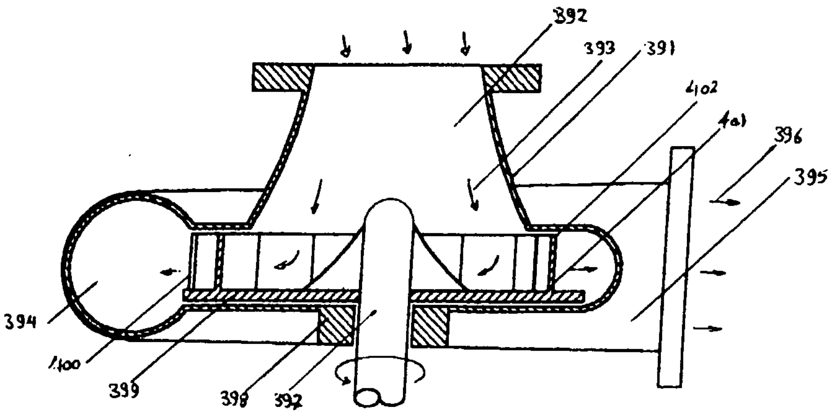
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FIG.32

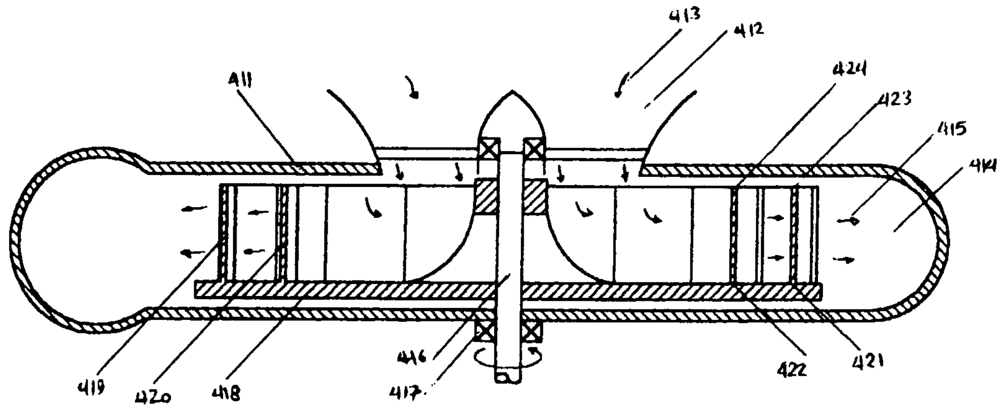
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FIG.33

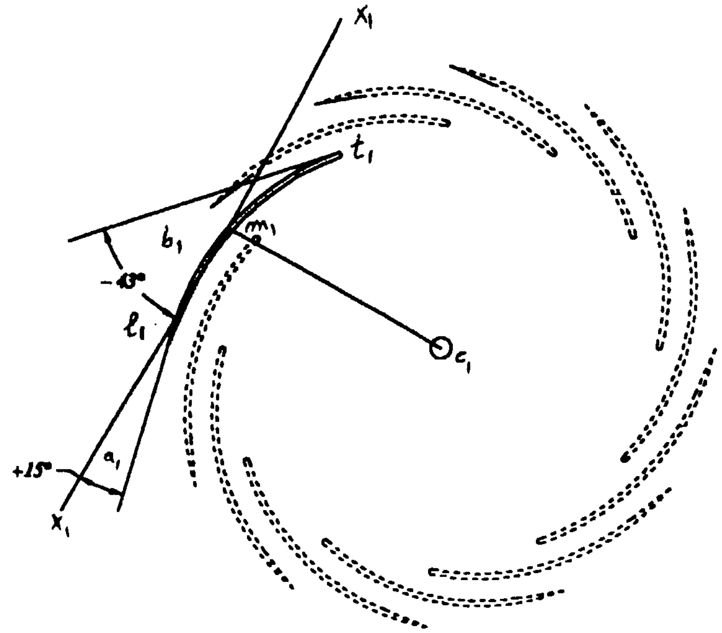

FIG.34

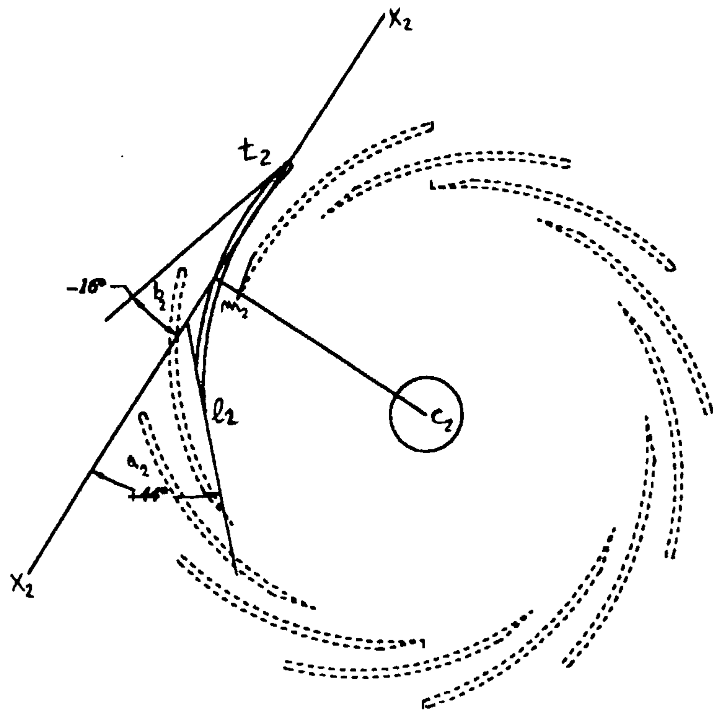

FIG.35

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/17044

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :F01D 1/06
US CL : 415/120
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 415/120; 416/178, 185, 186R, 187

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

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

USPTO EAST database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,195,965 A (MASNIK) 01 April 1980, Abstract, Figs. 8-11.	NONE
A	US 2,324,011 A (MILLER) 13 July 1943, Fig. 2.	NONE
A	US 3,536,416 A (GLUCKSMAN) 27 October 1970, Fig. 1.	NONE
A	US 4,165,950 A (MASAI et al) 28 August 1979, Fig. 2.	NONE
A	DE 27 54 582 A (MOSER) 13 June 1979, Fig. 1.	NONE
A	US 4,293,278 A (BACHL) 06 October 1981, Figs. 1, 5.	NONE

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 AUGUST 2000	12 OCT 2000

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	JOHN RYZNIC Diane Smith for
Facsimile No. (703) 305-3230	Telephone No. (703) 305-0060

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/17044

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 625,535 A (CHESTER) 29 June 1949, Figs. 3-5.	NONE
A	US 4,662,830 A (POTTEBAUM) 05 May 1987, Fig. 1.	NONE
A	US 45,755 A (SANDFORD) 03 January 1865, Fig. 2.	NONE
A	US 2,138,814 A (BRESSLER) 06 December 1938, Figs. 1,3,4.	NONE
A	US 5,427,503 A (HARAGA et al) 27 June 1995, Figs. 3,6,8,10.	NONE