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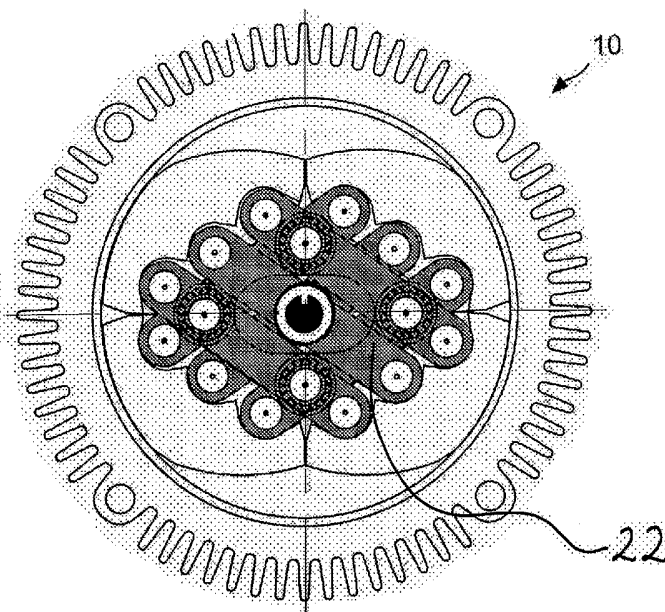
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(54) Title: **BALANCED ROTARY INTERNAL COMBUSTION ENGINE OR CYCLING VOLUME MACHINE**



(57) **Abstract:** A balanced rotary cycling machine suitable for use as an internal combustion engine, compressed gas or steam engine, compressor or pump is disclosed herein. The rotor assembly consists of four articulating pistons where the opposite pistons are inter-linked with each other by pivoted rods comprising a parallelogram mechanism and therefore eliminating a need for pivots between pistons. The rotor assembly rotates inside or outside of a circular or non-circular stator depending on the configuration chosen. A variety of mechanisms for shape deformation of four piston assembly during its rotating cycle is also disclosed herein, as well as detailed descriptions of preferred embodiments.

BALANCED ROTARY INTERNAL COMBUSTION ENGINE OR CYCLING VOLUME
MACHINE

TECHNICAL FIELD

[0001] This invention relates to a rotary engine or cycling machine with a unique piston arrangement.

BACKGROUND ART

[0002] Variable shape rotors are known from the prior art, as an example of which was provided by Werner in (U.S. Patent No. 716,970). Another type of engine was disclosed by Wankel, who established a rotary engine with a fixed shape rotor and epitrochoidal shape stator.

[0003] With the present invention, during the rotation cycle, the rotor pivoting blades or pistons align alternatively in a lozenge and a square configuration so that the volume between the blades itself, side walls and the stator (contour wall) changes, and in so doing, allows to create a cycling machine.

[0004] Rotary engines and cycling machines based on the principle set forth in Edward H. Werner's invention of 1902 (716,970) and further inventions developed in greater detail.

[0005] German Patent No. 1,295,569, provided a rotary internal combustion engine, in which two pistons are provided, which are connected to the shaft by means of two diametrically opposite arms fixedly connected to the shaft.

[0006] A contemporary embodiment of the cycling machine utilizing Werner's principle is described in U.S. Patent No. 6,164,263, in which roller carriages pivotally connected to the ends of the

blades create a lateral support for the rotor and simultaneously provide a cam surface for the rotor shape deformation. In this device, an additional variation of the volume between the blades, side covers and a stator, is achievable due to variation in relative positions of the carriages and blades.

[0007] Similar configurations are well known from prior art including U.S. patents by Jordan, Ishida and Niemland. These devices however, do not employ rollers at the end of sealing carriages, save for U.S. Patent No. 3,387,596, by Niemand where rollers are used in combination with a cam surface for deformation of the shape of a four blade parallelogram.

[0008] Parallelogram mechanisms for creating reciprocating movement of the pistons are known from U.S. Patent No. 5,203,295, issued to Alexander. Multiple applications of unique properties of the parallelogram mechanism are also known, for instance from PCT WO 09105990 by Okulov.

[0009] These arrangements are useful, however a common disadvantage exists in that the pivoting blades or links arranged in such configurations are extremely difficult to seal at the pivoting ends.

[0010] In respect of the sealing difficulties, different sealing techniques and methods have been described in U.S. Patent Nos 3,950,017; 3,690,791; 3,918,41; 4,296,936, etc. Several different types of seals are needed to provide adequate sealing of the device similar to U.S. Patent No. 6,164,263, which greatly complicates the design and compromises reliability. In addition, the complicated shape of the parts and greater surface area of the combustion chamber both determine high thermal losses and lower efficiency for this type of engine. Eliminating roller

carriages in order to create a simpler shape for the combustion chamber (or considering its size near zero) results in the devices similar to those described in a U.S. Patent, 3,918,415.

[0011] Other engines are represented by concepts proposed in the prior art and include a pressure energy converter, rotary engine or compressor as in U.S. Patent No. 4,068,985, 3,996,899; a rotary disk engine as in the U.S. Patent No. 5,404,850; a rotary planetary motion engine as in U.S. Patent No. 5,399,078; a rotary detonation engine as in the U.S. Patent No. 4,741,154; a rotary combustion engine as in DE patent 2,448,828, U.S. Patents Nos 3,933,131, 4,548,171, 5,036,809; the Wankel type engine as in the U.S. Patent Nos 3,228,183, 4,308,002, 5,305,721, and a continuous combustion engine as in the U.S. Patent No. 3,996,899. Most rotary engines, and particularly the Wankel and those described in the U.S. Patent Nos 3,442,257, 3,614,277, 4,144,866, 4,434,757, DE Patent No. 3,027,208 are based on the principle of volume variation between a curve and a moving cord of fixed length as a single sliding piston and have the common disadvantage of being unbalanced.

DISCLOSURE OF THE INVENTION

[0012] One aspect of one embodiment of the present invention is to provide an improved rotary internal combustion engine.

[0013] The present invention provides an engine or fully balanced cycling volume machine with a variably shaped rotor and low internal friction. The engine operates with reduced centrifugal forces on the oil or lubricant distribution and utilizes a conventional oil pan (pool) design solution which proved to be superior to other types of lubrication systems, particularly the ones used in conventional automobile engines.

[0014] A further aspect of one embodiment of the present invention is to provide a rotary cycling machine for producing mechanical energy from pressurized fluid as well as to pump, vacuum and compress fluids, comprising:

a hollow housing having an internal contour wall and having side covers parallel to each other and perpendicular to a central axis of the housing;

ports in communication with the interior of the housing for intake, exhaust, lubrication or cooling;

a piston assembly having pistons in spaced relation and mounted for rotational movement within the housing;

deformation means independent of the contour wall for deforming said piston assembly;

linkage means connected to opposed pistons for permitting relative movement of oppositely linked pistons, the linkage means being connected to the deformation means; and

sealing means between pistons of the piston assembly for providing a continuous seal between all pistons of the assembly during rotation.

[0015] The housing may comprise a stator and may optionally include a flexible liner which can cooperate with the sealing means to provide a very efficient and well sealed system.

[0016] In terms of the piston arrangement, the assembly may comprise a minimum of two pistons depending upon the use of the

cycling machine or up to four pistons arranged in a radial disposition and in sealing engagement with one another.

[0017] Depending upon the number of pistons, this will obviously vary the linkage means as well. The linkages may comprise a pair of linkage arms or a complete array where a group of arms are arranged for movement subscribing to a parallelogram configuration.

[0018] Still, another object of the present invention is to create an effective and simplified engine sealing system.

[0019] It is another object to create the possibility of using a simple circular shaped stator and an efficient combustion chamber.

[0020] Conveniently, the system of the invention provides for direct and linear transmission of mechanical torque from all four pistons to the shaft.

[0021] As an advantage, engine components such as cams, rollers and pivoting parts can be isolated from exposure to combustion gases, while the weight of the engine is reduced and provides for cleaner exhaust.

[0022] In view of efficiency of the design, the result is a lower rpm, more efficient engine, utilizing more efficient and less NOx.

[0023] The engine provides for lower dead time and is tolerant to different fuels and suitable for photo-detonation mode as well as hydrogen combustion.

[0024] Alternatively, another objective is to create an ignition device amplifying the internal pressure during the compression cycle to the point of ignition of air-fuel mixture and to provide an external combustion engine utilizing the compressor and expansion machines as per present invention. In this manner, the present invention provides for a rotary cycling machine for producing mechanical energy from pressurized fluid as well as to pump, vacuum and compress fluids, comprising:

a pair of rotary machines where the machines comprise:

a hollow housing having an internal contour wall and having side covers parallel to each other and perpendicular to a central axis of the housing;

ports in communication with the interior of the housing for intake, exhaust, lubrication or cooling;

a piston assembly having pistons in spaced relation and mounted for rotational movement within the housing;

deformation means independent of the contour wall for deforming said piston assembly;

linkage means connected to opposed pistons for permitting relative movement of oppositely linked pistons, the linkage means being connected to the deformation means; and

sealing means between pistons of the piston assembly for providing a continuous seal between all pistons of the assembly during rotation;

a first machine of the machines for compressing a fuel;

a combustion vessel for combusting compressed fuel from the first machine;

a second machine of the machines for receiving energy from combustion; and

a mechanical link between the first machine and the second machine.

[0025] The rotor in accordance with one embodiment of the present invention comprises an assembly of four pistons or blades suitable for creating variable volumes during a rotation cycle and having sealed gaps between adjacent pistons and an oval or circular shape stator. Oppositely disposed pistons are pivotally linked to each other creating a parallelogram mechanism and where the intersections of the links are connected to the rotor shape deforming mechanism and are also coupled with the output shaft.

[0026] The pistons can have individual seals with the stator and side covers creating variable volume chambers. Alternatively, the pistons may have seals between them, preferably at the centers of their relative rotation. Intake ports, spark plug and exhaust ports are provided either radially in the stator housing, or axially in the side covers, or both of these.

[0027] Different sealing techniques are further presented where sealing between pistons and side walls of the stator generally

constitute simple linear or curved semicircular spring loaded seals similar to the Wankel type engine seals. Apex seals are arranged either between the pistons and stator contour circular or oval wall or comprise additional seals supported in the mid angle between adjacent pistons and having apex seals with them. Other types of continuous seals when used are also disclosed.

[0028] Advantageously, rotation of the rotor provides the pistons rotor to generate cycling volumes thus enabling compression, expansion or vacuum. The engine with four pivoting pistons would have four strokes cycle firing four times per every revolution, practically without dead time.

[0029] In a further embodiment of the present invention, there is provided a rotary cycling machine for producing mechanical energy from pressurized fluid as well as to pump, vacuum and compress fluids, comprising:

- a hollow housing having an internal contour wall and side covers parallel to each other and perpendicular to a central axis of the housing;

- ports in communication with the interior of the housing for intake, exhaust, lubrication or cooling;

- a flexible piston assembly mounted for rotational movement within the housing;

- deformation means independent of the contour wall for deforming the piston assembly; and

- continuous sealing means between pistons of the piston assembly for providing a continuous seal between all pistons of the assembly during rotation.

[0030] As a particular advantage to the present invention, the flexible piston assembly may be one piece and thus can be extruded, molded or etched or formed by any other suitable manufacturing process. The use of the flexible piston assembly will have a particular value in certain engine types such as small engines used in garden tools, etc.

[0031] The design of the engine also provides for an engine configuration capable of creating a jet propulsory system and creating an engine for water crafts employing polymer plastic or composite parts cooled directly in the water.

[0032] In accordance with a further object of one embodiment of the present there is provided a rotary cycling machine for producing mechanical energy from pressurized fluid as well as to pump, vacuum and compress fluids, comprising:

a hollow housing having a stator wall and having side covers parallel to each other and perpendicular to a central axis of the housing;

ports in communication with the interior of the housing for intake, exhaust, lubrication or cooling;

a piston assembly surrounding the stator wall;

deformation means independent of the stator wall for deforming the piston assembly;

linkage means connected to opposed pistons for permitting relative movement of oppositely linked pistons, the linkage means being connected to the deformation means; and

sealing means between pistons of the piston assembly for providing a continuous seal between each piston and the stator of the assembly.

[0033] The engine described above is particularly useful in the marine applications since the blades or propulsors of different varieties can be directly mounted onto the pistons which orbit the stator.

[0034] In terms of the ports for exhaust dispersion and intake, the exhaust port may be positioned so that the exhaust is discharged directly into a water stream in the event that the engine is used as a marine engine with an intake in a position suitable for fuel intake, air intake, etc.

[0035] In accordance with a further object of one embodiment of the present invention there is provided a linkage mechanism for linking piston members in a rotary engine, said engine having a stator and piston members, comprising:

first linkage arms having spaced apart ends;

second linkage arms having spaced apart ends arranged in a parallel plane relative to the first linkage arms;

connection means at each end of the spaced apart ends of the arms for movably connecting opposed pairings of the piston members;

roller means connected to arms of the first arms and the second arms for facilitating movement between connected arms of the first arms and the second arms;
and

cam means about which the rollers orbit for movement of the piston members.

[0036] The arrangement is particularly effective for advancement of the pistons and, as discussed herein previously, the movement of the linkage arms essentially moves from a substantially square arrangement to a rhomboidal arrangement and is conveniently positioned between the space defined by the pistons.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] Figure 1 illustrates four segmental articulating pistons arranged in a lozenge configuration;

[0038] Figure 2 illustrates the pistons arranged in a square configuration;

[0039] Figures 3 through 8 illustrate cycles of the engine operation;

[0040] Figures 9 and 10 illustrate the prior art arrangements;

[0041] Figure 11 is a plan view of the preferred embodiment with part of the side cover and links not shown;

[0042] Figure 12 is a sectional view of the engine along line 12-12 of Figure 11;

[0043] Figures 13 through 14B illustrate methods of deformation of pistons assembly utilizing non-circular gears and/or rollers;

[0044] Figures 15 through 18 illustrate variants of stator and rotor possible arrangements;

[0045] Figure 19 is an enlarged view of the described piston bed surrounding the contour wall with side covers;

[0046] Figures 20 through 22 illustrate the sealing system according to one preferred embodiment;

[0047] Figure 23 is a representation of the geometry of the outer portion of a segmental piston (providing for a minimum volume between the piston and contour wall);

[0048] Figure 24 illustrates a variant of the rotor assembly with flexural pivots between pistons and flexural apex seals;

[0049] Figures 25 through 25D illustrate the machine and a lubrication system therefor;

[0050] Figure 26 is a perspective view of a seal element;

[0051] Figure 27 is a perspective view of a seal for use in the machine;

[0052] Figure 28 is a longitudinal cross-section of Figure 27;

[0053] Figure 29 is a perspective view of the spring for use in the seal of Figures 27 and 28;

[0054] Figure 30 is a view of the seal in one embodiment;

[0055] Figure 31 is a view of the seal in another embodiment;

[0056] Figure 32 is a schematic representation of the seal of Figures 30 and 31;

[0057] Figure 33 is a representation of the geometry of one quadrant of the engine circular contour wall and with possible positions of one of the segmental pistons;

[0058] Figure 34 illustrates the geometry of the circular stator (contour wall) and half circle shape of segmental pistons;

[0059] Figure 35 is a representation of the geometry of the cycling machine with a non-circular shape, symmetrical contour wall or cam surface;

[0060] Figure 36 illustrates variations of possible shapes of a symmetrical non-circular contour wall or cam surface;

[0061] Figures 37 through 38A illustrate the method of mathematical definition of the contour wall or cam geometry, particularly with non-symmetrical configuration described in a Figure 38A;

[0062] Figure 39 is a variant of the engine with combustion chambers defined by a contour wall and pistons surrounding it;

[0063] Figure 40 is an elevational view of the engine of Figure 39 schematically illustrating the lubrication system and oil pan;

[0064] Figure 41 is another view similar to Figure 13 showing the piston assembly in lozenge configuration;

[0065] Figure 42 illustrates an engine configuration with pistons coupled directly with fins and surrounding a non-circular stator;

[0066] Figure 43 illustrates an amplified compression type ignition plug;

[0067] Figure 44 illustrates a graphical representation of the method of amplification of pressure inside the ignition chamber of the plug of Figure 43; and

[0068] Figures 45 and 46 illustrate the principle of an external combustion engine according to the present invention.

INDUSTRIAL APPLICABILITY

[0069] The present invention has applicability in the engine art.

MODES FOR CARRYING OUT THE INVENTION

[0070] Figure 1 illustrates a cross-sectional view of the rotary apparatus, generally denoted by numeral 10. Figures 11 and 12 illustrate a side and partially cutaway view of the arrangement 10, respectively. With respect to Figures 1, 11 and 12, the arrangement 10 provides a housing 12 having end covers 14 within which is disposed a stator 16. The stator is shown as a circular arrangement; however, the arrangement may also be of a semi-circular shape or have an adjustable liner to be discussed hereinafter.

[0071] Disposed within housing 12 is a plurality of pistons 18. Pistons 18 have a general arc shape for contact with stator 16. The internal area of the pistons includes a plurality of generally rounded or scalloped portions 20. The scalloped portions are configured to permit general movement of linkages 22.

[0072] As illustrated, diametrically opposed pairings of pistons 18 are connected by linkages 22. Each of linkages 22 includes at either end connecting axles 24. In this manner, each of the linkages allows for movement of piston 18 relative to linkage 22,

the movement being accommodated by the piston scalloped sections 20.

[0073] In Figure 1, linkage arms 22 for an opposed pairing of pistons 18 overlies linkage arms 22 of the opposing pairing of pistons. To connect the opposed individual pairings of pistons 18, overlying linkage arms 22 are connected together for relative movement. This is achieved by axles of rollers 26 which connect alternating individual linkage arms of one layer with similar arms from the second layer. Linkage arms 22 are effectively arranged in an array with rollers 26 connecting alternating arms of the first array or top layer with the similar arms from the second array or underlying group of linkage arms 22. This effectively connects linkage arms 22 of opposed pairings of pistons 18 with the second opposed pairing. As is illustrated in Figure 1, rollers 26 are positioned at the point of intersection between connected first layer and second layer linkage arms 22.

[0074] Extending through housing 12 and covers 14 is a central shaft 28 having a generally cross-shaped coupling member 30, having slots for engagement with the axes of rollers 26 illustrated in Figure 11. A central shaft support 32 is coaxially arranged about central shaft 28 and includes radial and thrust bearings 34.

[0075] The shape of the rotor assembly changes from the lozenge shape of Figure 1 to the square configuration as illustrated in Figure 2 by the piston deformation assembly. As illustrated in Figure 1, the rollers 26 effectively change from a rhomboidal configuration to a substantially square configuration under the action of the deformation mechanism. As an example, the deformation mechanism can comprise a cam member or members 36. In the example, cam 36 is generally ovular and symmetrical,

however it will be understood that the underlying concept with respect to the shape is that the same must include at least one minimum and one maximum curvature. In this regard, although illustrated in ovular shape, by consideration of the minimum maximum curvature other shapes are possible. Cam arrangement 36 may be an integral part of shaft support 32 or, the deformation mechanism can include non-circular gear arrangements or pivoting members or others. An alternative is illustrated in Figures 13 through 14B. In this arrangement, the deformation arrangement may include non-circular gear members 38 together with central static gear 40 comprised of cylindrical member 42 having teeth 44.

[0076] In use, and returning to the arrangement in Figures 1, 11 and 12 by virtue of rollers 26 and the disposition of the axes being at intersections of links 22, the deformation system allows rocking of the system against the cam arrangement.

[0077] In Figures 3 through 8, the overall operation of the arrangement is shown with only four linkage arms 22. Ports for intake and exhaust are denoted by numeral 46a and an example of a spark plug is denoted by numeral 26a. Linkage arms 22 and specifically the disposition of rollers 26 relative to one another, alternatively changes from a rhomboidal configuration to a square configuration.

[0078] A simple variation of the number of intake ports and exhaust ports of the arrangement shown in Figures 3 through 8 can be modified so that the engine can operate as a two-cycle or two-stroke engine. Further, the inner-cycling volume of the engine, i.e. volume between the pistons, or an external blower may also be utilized.

[0079] One of the primary advantages of the engine set forth herein is realized by the fact that the deformation mechanism is not part of the stator, rotor or contour wall. This permits adjustment of burn properties to burn different fuels, create different compression ratios, modify the relationship between the combustion/intake/expansion chambers volume and angles of the rotor assembly rotation. Clearly, this translates into an arrangement where horsepower can be augmented with relative ease without having to extensively reconstruct the arrangement or simply discard the housing rotor, etc. This is advantageous over the limitations in the structures of the prior art.

[0080] The pistons 18 may include a hollow volume 46 (Figure 12). The number of pistons 18 will vary from one application to another with a minimum of two pistons. A "chain-like structure" can be achieved with multiple chambers or a "wavy" disc coupled with a single or multiple tiltable chambers. This configuration may effectively be used in pumps, pneumatic breaks for vehicles (a pump with a closed output and a "wavy" disc like stator), propulsors for a watercrafts, etc. A variety of possible arrangements of pistons 18 and stators 12 are shown in Figures 15 through 18 where chambers 48 are created between them.

[0081] In respect of the sealing system of pistons, pistons 18 as illustrated in Figure 19 as an example, may include lateral seals 50, disposed along the inside wall of the side covers 14 with additional seals 52 for contact with the contour wall or "wavy disk stator/rotor" (not shown).

[0082] Figure 20 illustrates additional sealing arrangements where the individual pistons include apex seals 54, lateral seals 56 and inter-piston seals 58. Figure 21 illustrates an enlarged section of the apex and lateral seal system. Figure 22

illustrates preferred configuration for the sealing where a spring 60 loads apex seal 54 and apex seal 62. This is similar to the Wankel-type engine seals, however, the advantage with this arrangement is that there is a much more favourable leaning angle associated with the apex seals. This is found to be best when the leaning angle is not greater than 10 degrees compared to between 16 and 30 degrees for Wankel-type engines. In respect of the leaning angle, reference can be made to Figure 23. Inter-piston seals 58 can be arranged in the form of flexible members.

[0083] Further, continuous seals may also be employed in combination with a toroidal stator or toroidal shape rotor pistons. The seals are as effective as conventional piston engine seals. One of the beneficial features of the arrangement is that the rotor assembly and seals, shown in Figure 24 and represented by numeral 62, can be a one-piece molded, extruded or etched part with pistons 18, inter-piston flexural links 64 with spring loaded flexible apex seals with the spring being noted by numeral 66 and apex seal 68.

[0084] In Figures 25 and 26 through 32, shown is a further variation on the sealing arrangement according to the present invention. The inter-piston seals according to Figure 25 and generally denoted by numeral 70 may comprise a generally cylindrical structure which may include a plurality of sections 72 and 74 where the sections are moveable relative to one another. Cylindrical sealing element 70 may be tubular and include a sealing insert 76 disposed coaxially therein. Sealing insert 76 also may include a longitudinal bore 78 within which is disposed a torsional spring 80. Spring 80 and insert 76 are disposed within the cylindrical sealing element such that the end portions of the spring are turned downwardly and extend through the insert as illustrated in Figure 28. The sealing member may

be isolated into sections 72 and 74 by a zigzag cut or by a helical cut as illustrated in Figure 27.

[0085] Spring 80 is a torsional spring and would facilitate rotation in opposed directions of the individual segments 74 and 76 which in turn will facilitate axial movement of said segments, best illustrated in Figure 32. The arrangement is shown where the sections 72 and 74 are connected and secondly where the sections have slightly pulled apart from one another, thus introducing a gap 82 between sections 72 and 74. With the torsional spring, the seal can provide both axial, i.e. in the direction of the central shaft sealing, as well as radial sealing. In this manner, the seal is effectively a "dynamic" seal and adjusts by movement of the body itself relative to stresses experienced during rotation of the pistons.

[0086] Returning now to a discussion on the pistons, the height of each piston may be approximately equal to half of its length. See as illustrated in Figures 33 and 34. This provides a minimum variation in the clearance between the top of the piston and the contour of the stator circular wall as graphically illustrated in Figure 23. As an example, with a stator inner-diameter of 100 millimeters (4 inches) the length of the piston may be 54 millimeters (2.13 inches) with the height comprising 23 millimeters (0.9 inches). The variation in the gap between the apex of the piston found at apex seal 54 (Figures 20 and 21) will be in the range of between 0 and 0.3 millimeters (0-0.012 inches). This minor variation can be easily accommodated by movement in the seating of the seal. Alternatively, this variation can be canceled by providing a slightly non-circularly shaped stator by either machining or deforming a flexural stator or liner. This is generally illustrated in Figures 38 and 38A.

[0087] The "ideal geometrical configuration" (as established in Figures 33 and 34) involves piston segments of equal to or less than twice the radius of the stator contour wall. Sealing in this configuration in high RPM devices can employ the "close to zero" gap technique where, depending on the density of the working fluid, very sufficient pressures can be achieved without seals at all, but with minimum clearance between the parts. This particular configuration would be preferable with ceramic, composite or plastic parts employed which may be especially advantageous for lubricant-free engines as well as in micro-engines etched from silicon-based materials.

[0088] The geometry of other variations and details of engines and cycling volume machines is set forth in Figures provided herein. The variation shapes of the "oval" stator or geometry of the cam surfaces (Figures 35 and 36) as well as their semi-symmetrical types (Figure 38A) and other parameters are numerous and may be analyzed using mathematical analysis techniques.

[0089] The geometry chosen will determine the compression ratio and displacement of the engine. The shape of the curve must conform with two points, namely points 1 and 2 in Figure 35 or Figure 38A. The distance between the points must equal the side of the C^2 and a polar angle between them must be equal to 90 degrees. Such a curve has an infinite amount of geometrical solutions predetermined by the ratio A/B and by at least one fragment of the curve between points 4 or 6 and 5 which are reference points for all possible curves with a similar ratio of A/B . Point 5 is a common reference point for all possible symmetrical curves. Figures 37 through 38A illustrate the method of mathematical definition of the contour wall.

[0090] As a particularly favourable feature of the present invention, the compression ratio of the instant engine is not limited by its geometry, which is contrary to the Wankel-type engine where the compression ratio cannot exceed 15.5:1 for a three-lobe rotor. The displacement of engines made in accordance with the present invention is to be compared to a four-cylinder, four-cycle engine since it will have an equal number of power strokes per one revolution of the shaft. As an example, the circular stator shape engine of the present invention with the displacement of 2.7 liters will have a contour wall diameter of approximately 12 inches and a thickness of 3.3 inches.

[0091] In a preferred embodiment, central shaft 28, as indicated previously has a cross-leg shape coupling member 86 with slots 88 where engaging the axes of linkage arms 22. As an alternative, the torque and lateral forces resulting from the pressure within housing 12 can be transferred through the pistons depending on the configuration chosen.

[0092] Referring now to Figures 39, 40, 19 and 41, the engine with a non-circular or oval-shaped stator 16 may be provided with different types of chamber arrangements. In one possible embodiment, as illustrated in Figure 39 there is included housing 12 having the pistons surrounding the stator ring from the inner or outer portion of the stator ring to create a corresponding number of chambers 90. In the situation where the pistons are positioned inwardly, the possibility exists to employ a conventional oil pan 92 (Figure 40) for lubrication which simplifies the design, improves reliability and provides for low emissions.

[0093] Lubrication can include filter 94, oil radiator 96 and pump 98. Distribution can be effected through central shaft 28

having passages 100 there through. The distribution can be assisted by centrifugal forces which will facilitate circulation.

[0094] Returning to Figures 25 through 25D, shown are greater details concerning a lubrication system according to further embodiments of the present invention. In respect of Figure 25, as discussed with respect to Figure 40, the central shaft includes passageways 100 within which the oil may be dispersed. In the embodiment of Figures 25 and 25B, pistons 18 include within hollow areas 46 lubricant or oil which can be recirculated through the system via the pistons and central shaft 28. To this end, the pistons may include oil pumps, globally denoted by numeral 102 and illustrated in Figure 25A. As illustrated in Figure 25A, the overall oil pump mechanism is part of the extensions of the central shaft 28 and is immersed in the oil 46.1. Within piston 18 is a chamber within which the pump mechanism 102 operates. In greater detail, Figures 25A, 25C and 25D illustrate the components of the pump mechanism. Within the body of piston 18 there is a chamber 102.1 within which a moveable plunger 102.2 is slidable from the position shown in Figure 25C to the position shown in Figure 25D. Plunger 102.2 is actuated by a spring member 102.3 disposed within or adjacent to the body of plunger 102.2. An O-ring member 102.4 facilitates sealing of plunger 102.2 during its movement (extension and retraction) shown in Figures 25D and 25C, respectively. A ball valve assembly 102.5 is positioned about opening 102.1. The assembly includes ball valves 102.6 and 102.7 which are retained by retaining member 102.8. As is evident from Figures 25C and 25D ball valves 102.6 and 102.7 and plunger 102.2 cooperate during articulation of pistons 18 such that oil is either admitted as shown in Figure 25D or discharged as shown Figure 25C where the discharge of the oil is passed through channel 102.9 for eventual readmission into channels 100 of central shaft 28.

[0095] Turning to possible alternatives for the instant technology, the engine may be incorporated by watercraft devices with the respective parts being composed of suitable polymeric materials, composites, etc. with the entire engine capable of being submerged in the water for effective cooling. This embodiment is generally illustrated in Figure 42. In the embodiment, each piston can have a blade 106 schematically shown in Figure 42, or other suitable water displacing structure directly attached to the piston. The configuration of pistons can include cover permitting desirable shape for controlling fluid dynamics.

[0096] In respect of four stroke combustion engines, the four chambers may be used in a closed circuit with the cycles defined as follows: intake, compression, expansion and exhaust (Figures 3 through 8). The intake ports may utilize conventional carburetor technology or can be fitted with a gas or diesel fuel injector (not shown). Alternatively, the fuel may be injected directly into the chamber. It is also envisioned that continuous combustion can be achieved by utilizing a flame pilot technique or providing a channel between the chambers. As a further alternative to a conventional spark plug 26a (Figures 3 through 8), or a pair of such plugs custom to Wankel-type engines, a compression diesel igniter such as that shown in Figure 43 and represented by numeral 110, may be used where the pressure of an air/fuel mixture is mechanically multiplied by a differential piston 112, 114 with the pressure and displacement being illustrated in Figure 44. Upon reaching a certain displacement, a spring 116 of igniter 110 sliding within a liner 118 confines the chamber 1 to P_2 .

[0097] The ignition timing may be achieved using electronic ignition or controlling the injection of fuel directly into the combustion chamber. The conventional spark plug cavity can be exposed to the inner volume of the chamber by means of porting the bi-rotation of the pistons.

[0098] The engine as set forth herein advantageously does not require a flywheel as the inertial capability of the piston assembly is sufficient to provide smooth rotation even on low RPMs. The projected maximum RPM of the engine is between about 3000 and 5000 RPM due to the quadruple firings per revolution which, in many instances, requires a significantly less complicated gear box or no gear box whatsoever.

[0099] In terms of cooling, the engine may be cooled by air, water or oil or in any traditional fashion for rotary engines. Where an oil pan is employed, the intensive circulation with the oil together with an external heat exchanger and filter, as discussed herein previously, may be used. More over, as a single rotor engine can be easily scaled up for achieving of quite a sufficient power rating, a direct air cooling system can preferably be employed allowing cooling of the engine housing uniformly from all sides. In addition, the asymmetrical pattern of heating predetermined by fixed position of combustion chamber can be easily smoothen by integration of an oil cooling exchanger into a coldest part of the stator itself, therefore reducing thermal stresses to the engine parts.

[00100] The engine in accordance with the present invention may be used as an expansion type machine compatible with numerous types of fluids such as steam, compressed or liquefied gasses, hydrogen, etc.

[00101] As a further alternative, as illustrated in Figures 45 and 46, two cycling machines may be arranged in a way that one machine 124 compresses an oxidizer such as air, and delivers it along with fuel into a high pressure combustion chamber 126 having a thermal insulation liner 128, where the energy of the products of continuous and easily optimized combustion will be fed into the expansion machine 130 through a thermally-insulated passage 132. Part of the energy created may be returned to the compressor 124 by a mechanical or electro-mechanical link 134.

[00102] Figures 45 or 46 further illustrate a similar configuration of the external engine employing a hybrid system where the compressor 124 is driven by an electric motor or where the expansion machine is assisted by electric motor (not shown) as well as a machine where the exhaust will be fed back to the outer part of the combustion chamber 128 with an additional shell 136.

CLAIMS

1. A rotary cycling machine for producing mechanical energy from pressurized fluid as well as to pump, vacuum and compress fluids, characterized in that said machine comprises:

a hollow housing having an internal contour wall and having side covers parallel to each other and perpendicular to a central axis of the housing;

ports in communication with said interior of said housing for intake, exhaust, lubrication or cooling;

a piston assembly having pistons in spaced relation and mounted for rotational movement within said housing;

deformation means independent of said contour wall for deforming said piston assembly;

linkage means connected to opposed pistons for permitting relative movement of oppositely linked pistons, said linkage means being connected to said deformation means; and

sealing means between pistons of said piston assembly for providing a continuous seal between all pistons of said assembly during rotation.

2. The machine as set forth in claim 1, characterized in that said hollow housing is a substantially cylindrical housing.

3. The machine as set forth in claim 1, characterized in that said hollow housing is a cylindrical housing.
4. The machine as set forth in claim 1, characterized in that said sealing means is a continuous seal with respect to said internal contour wall.
5. The machine as set forth in claim 1, characterized in that said contour wall includes a flexible liner.
6. The machine as set forth in claim 1, characterized in that said piston assembly comprises at least two individual piston members.
7. The machine as set forth in claim 1, characterized in that said piston assembly comprises a quartet of individual piston members.
8. The machine as set forth in claim 6, characterized in that said individual piston members are sealed relative to one another and said interior contour wall.
9. The machine as set forth in claim 7, characterized in that said individual piston members are sealed relative to one another and said interior contour wall.
10. The machine as set forth in claim 6, characterized in that opposed pairings of said individual piston members are directly linked by said linkage means for parallel movement.
11. The machine set forth in claim 6, characterized in that said individual piston members have a continuous substantially arc shaped profile with an apex for following said contour wall.

12. The machine as set forth in claim 4, characterized in that said continuous sealing means includes a discrete sealing element between adjacent individual piston members.
13. The machine as set forth in claim 12, characterized in that each discrete sealing element comprises a tubular member configured for sealing engagement with adjacent piston members.
14. The machine as set forth in claim 13, characterized in that said tubular member is segmented into a plurality of individual sections moveable relative to one another.
15. The machine as set forth in claim 13, characterized in that said tubular member is segmented into at least two mating segments defined by a helical interface.
16. The machine as set forth in claim 13, characterized in that said tubular member includes a sealing insert coaxially disposed within said tubular member.
17. The machine as set forth in claim 16, characterized in that said sealing insert is continuous and includes a coaxially disposed spring means having terminal ends connected to said tubular member.
18. The machine as set forth as in claim 16, characterized in that said sealing insert is at least partially flexible for torsional and axial deformation of sections of said tubular member.
19. The machine as set forth in claim 11, characterized in that each said apex of said piston members includes a seal.

20. The machine as set forth in claim 1, characterized in that said piston members include an auxiliary seal.
21. The machine as set forth in claim 1, characterized in that said deformation means includes a cam and a plurality of rollers for orbiting said cam.
22. The machine as set forth in claim 21, characterized in that said cam has at least one maximum and one minimum curvature.
23. The machine as set forth in claim 21, characterized in that said cam is asymmetrical in shape.
24. The machine as set forth in claim 21, characterized in that said cam is ovular.
25. The machine as set forth in claim 21, characterized in that said deformation means includes a plurality of cams.
26. The machine as set forth in claim 21, characterized in that said rollers facilitate movement of said linkage means.
27. The machine as set forth in claim 1, characterized in that said linkage means comprises a plurality of linkage arms having spaced apart ends.
28. The machine as set forth in claim 27, characterized in that each end of said spaced apart ends is pivotally connected to a piston member of a pair of opposed pairings.
29. The machine as set forth in claim 27, characterized in that said linkage arms of opposed pairings of pistons intersect.

30. The machine as set forth in claim 28, characterized in that said linkage arms of opposed pairings of pistons intersect in at least four points.
31. The machine as set forth in claim 28, characterized in that said linkage arms of opposed pairings of pistons intersect at eight points.
32. The machine as set forth in claim 1, characterized in that said deformation means is removably and entirely mounted within said interior volume of said piston assembly.
33. The machine as set forth in claim 1, characterized in that said machine is four stroke.
34. The machine as set forth in claim 1, characterized in that said machine is two stroke.
35. The machine as set forth in claim 1, characterized in that said machine is a pulse jet engine with at least one exhaust port associated with jet nozzle.
36. The machine as set forth in claim 1, characterized in that said machine further includes a centrifugally operated oil system.
37. The machine as set forth in claim 1, characterized in that said piston members include an oil reservoir for retaining and dispersing oil.
38. The machine as set forth in claim 36, characterized in that centrifugally operated oil system includes passageways within said central shaft in fluid communication with said pistons.

39. The machine as set forth in claim 38, characterized in that said passageways include a valve responsive to the displacement produced by a relative movement of said piston assembly to facilitate opening and closure of said valve for circulation of oil through said pistons and said central shaft.
40. The machine as set forth in claim 36, characterized in that said oil system further includes means for cooling said oil.
41. The machine as set forth in claim 36, characterized in that said oil system further includes means for cleaning said oil.
42. The machine as set forth in claim 37, characterized in that said oil reservoir has an individual oil pump immersed in.
43. A rotary cycling machine for producing mechanical energy from pressurized fluid as well as to pump, vacuum and compress fluids, characterized in that said machine comprises:

a hollow housing having an internal contour wall and side covers parallel to each other and perpendicular to a central axis of the housing;

ports in communication with said interior of said housing for intake, exhaust, lubrication or cooling;

a flexible piston assembly mounted for rotational movement within said housing;

deformation means independent of said contour wall for deforming said piston assembly; and

continuous sealing means between pistons of said piston assembly for providing a continuous seal between all pistons of said assembly during rotation.

44. The machine as set forth in claim 43, characterized in that said flexible piston assembly is a continuous assembly.
45. The machine as set forth in claim 43, characterized in that said flexible piston assembly is a one piece assembly.
46. The machine as set forth in claim 45, characterized in that said one piece assembly is an extruded assembly.
47. The machine as set forth in claim 45, characterized in that said one piece assembly is an etched assembly.
48. The machine as set forth in claim 45, characterized in that said one piece assembly is a molded assembly.
49. The machine as set forth in claim 43, characterized in that said internal contour wall comprises a stator wall and includes a flexible liner.
50. A rotary cycling machine for producing mechanical energy from pressurized fluid as well as to pump, vacuum and compress fluids, characterized in that said machine comprises:

a hollow housing having a stator wall and having side covers parallel to each other and perpendicular to a central axis of the housing;

ports in communication with said interior of said housing for intake, exhaust, lubrication or cooling;

a piston assembly surrounding said stator wall;

deformation means independent of said stator wall for deforming said piston assembly;

linkage means connected to opposed pistons for permitting relative movement of oppositely linked pistons, said linkage means being connected to said deformation means; and

sealing means between pistons of said piston assembly for providing a continuous seal between each piston and said stator of said assembly.

51. The machine as set forth in claim 50, characterized in that said stator wall is ovular in shape.
52. The machine as set forth in claim 50, characterized in that said stator wall is substantially cylindrical.
53. The machine as set forth in claim 50, characterized in that said stator wall includes a flexible liner for cooperation with said sealing means.
54. A linkage mechanism for linking piston members in a rotary engine, said engine having a stator and piston members, characterized in that said machine comprises:

first linkage arms having spaced apart ends;

second linkage arms having spaced apart ends arranged in a parallel plane relative to said first linkage arms;

connection means at each end of said spaced apart ends of said arms for movably connecting opposed pairings of said piston members;

roller means connected to arms of said first arms and said second arms for facilitating movement between connected arms of said first arms and said second arms; and

cam means against which said rollers orbit for movement of said piston members.

55. The linkage mechanism as set forth in claim 54, characterized in that said cam means has an ovular shape.
56. The linkage mechanism as set forth in claim 54, characterized in that said first arms and said second arms each comprise a plurality of arms.
57. The linkage mechanism as set forth in claim 54, characterized in that said mechanism includes three first arms and three second arms.
58. The linkage mechanism as set forth in claim 54, characterized in that alternating similar arms of said first arms and said second arms are connected by axles of said rollers.
59. The linkage mechanism as set forth in claim 54, characterized in that said linkage arms, connection means, roller means and cam means are disposed between said pistons.

60. The linkage mechanism as set forth in claim 54, characterized in that said first linkage arms are connected to a first pair of opposed pistons.
61. The linkage mechanism as set forth in claim 54, characterized in that said second linkage arms are connected to a second pair of opposed pistons.
62. The linkage mechanism as set forth in claim 54, characterized in that said arms are connected to said pistons for movement of said pistons about said stator.
63. The linkage mechanism as set forth in claim 54, characterized in that said arms are connected to said pistons for movement of said pistons within said stator.
64. The linkage mechanism as set forth in claim 54, characterized in that said mechanism is self contained within said interior volume.
65. The linkage mechanism as set forth in claim 54, characterized in that said mechanism is connected to define a parallelogram and movable to cycle from a substantially square configuration to a substantially rhomboidal configuration.
66. A method for effecting movement of pistons within a rotary engine having a rotor and a quartet of spaced apart pistons arranged to define an internal volume housed within a housing, characterized in that said method comprises the steps of;

providing a plurality of linkage arms for connecting opposed pairings of pistons where said

linkage arms of one opposed pairing of pistons intersects with linkage arms of a second opposed pairing of said pistons;

connecting linkage arms of said one opposed pairing of pistons with linkage arms of a second opposed pairing of said pistons to permit reciprocal movement there between;

positioning a cam member between points of connection of said linkage arms to enable orbital travel of said linkage arms about said cam;

effecting movement of said rotor; and

rotating said pistons during which connected linkage arms alternate between a rhomboidal and square configuration within said interior volume.

67. A rotary cycling machine for producing mechanical energy from pressurized fluid as well as to pump, vacuum and compress fluids, characterized in that said machine comprises:

a pair of rotary machines where said machines comprise:

a hollow housing having an internal contour wall and having side covers parallel to each other and perpendicular to a central axis of the housing;

ports in communication with said interior of said housing for intake, exhaust, lubrication or cooling;

a piston assembly having pistons in spaced relation and mounted for rotational movement within said housing;

deformation means independent of said contour wall for deforming said piston assembly;

linkage means connected to opposed pistons for permitting relative movement of oppositely linked pistons, said linkage means being connected to said deformation means; and

sealing means between pistons of said piston assembly for providing a continuous seal between all pistons of said assembly during rotation;

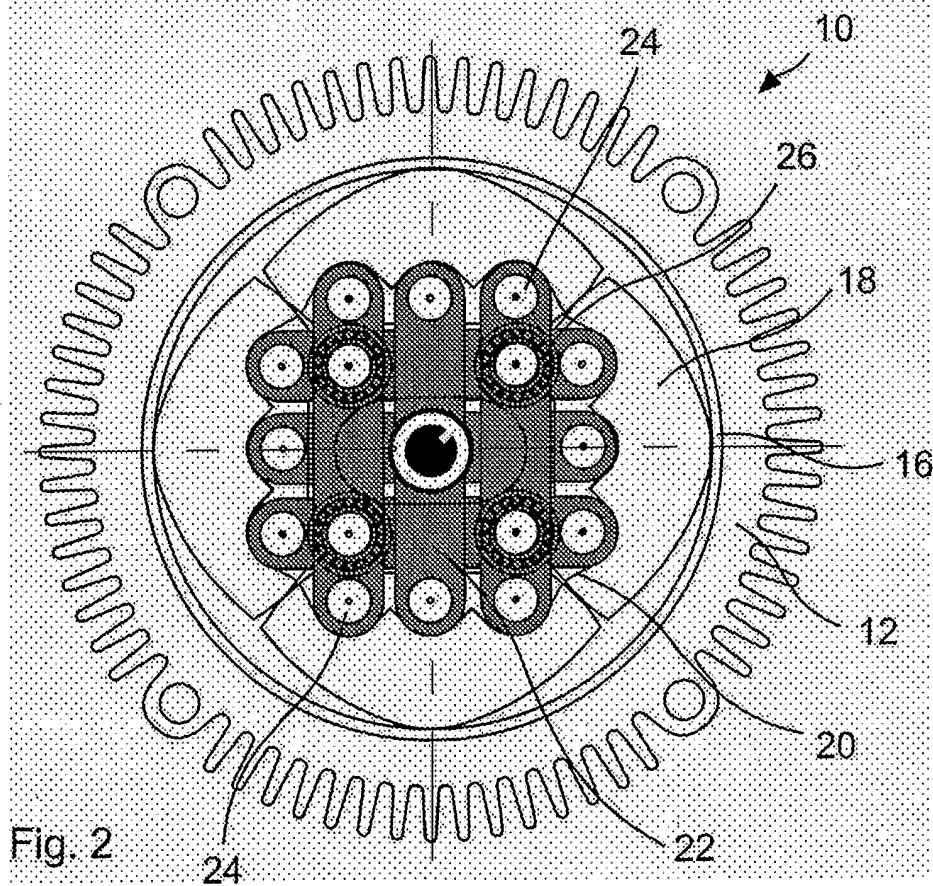
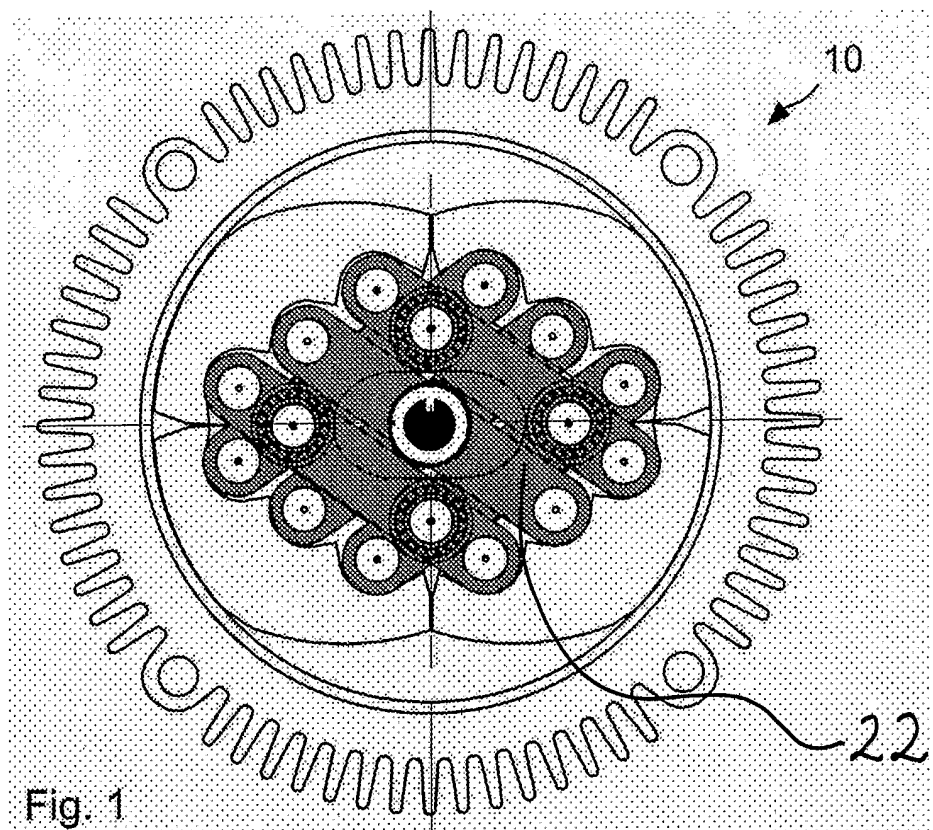
a first machine of said machines for compressing a fuel;

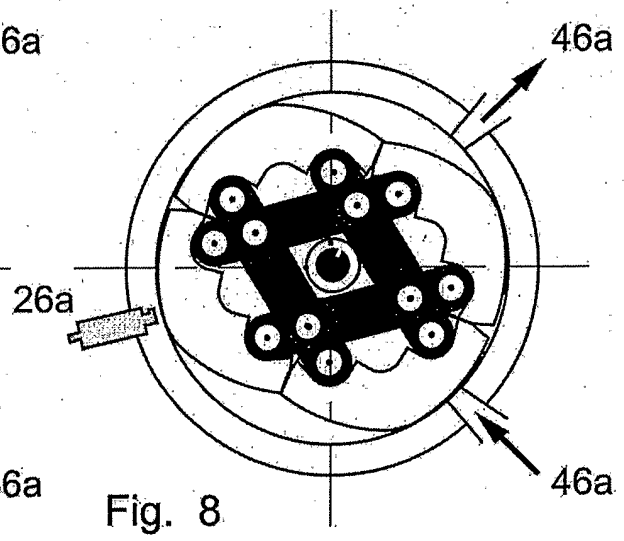
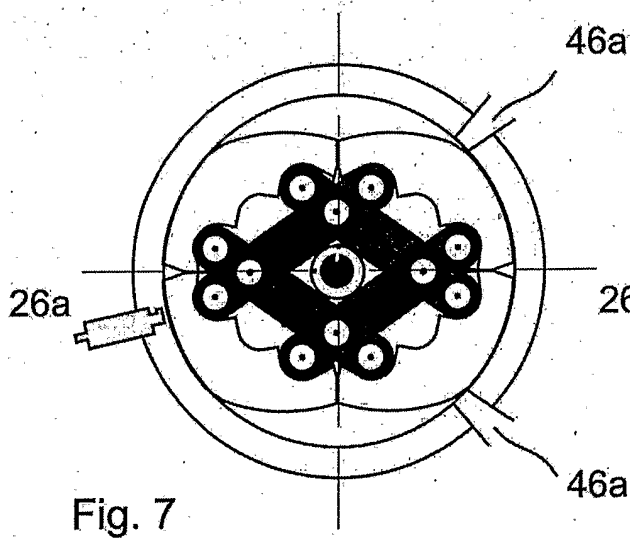
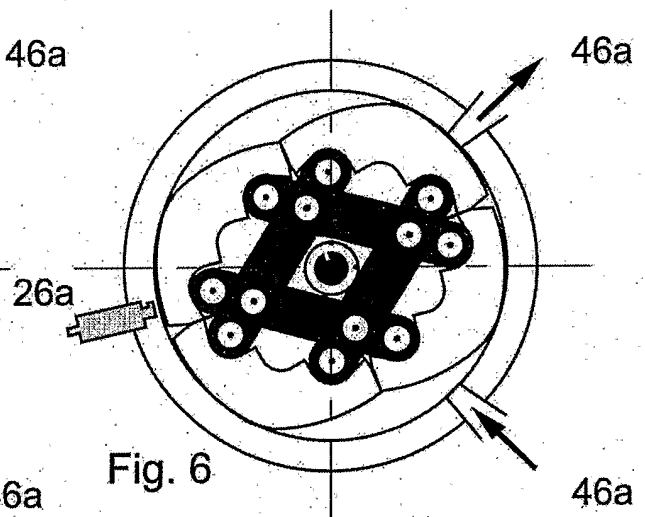
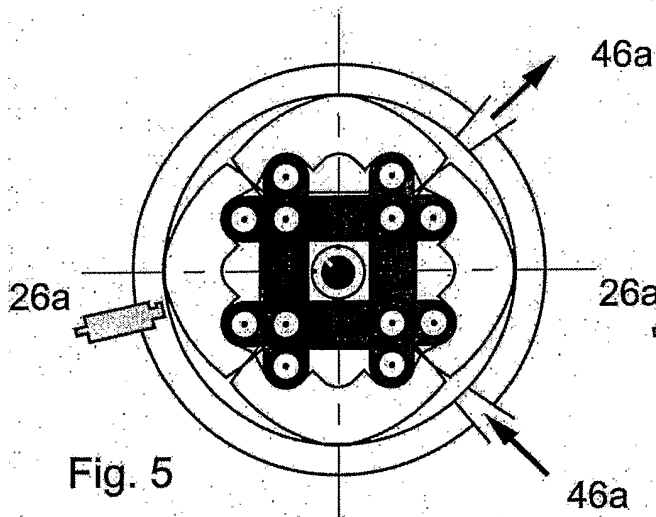
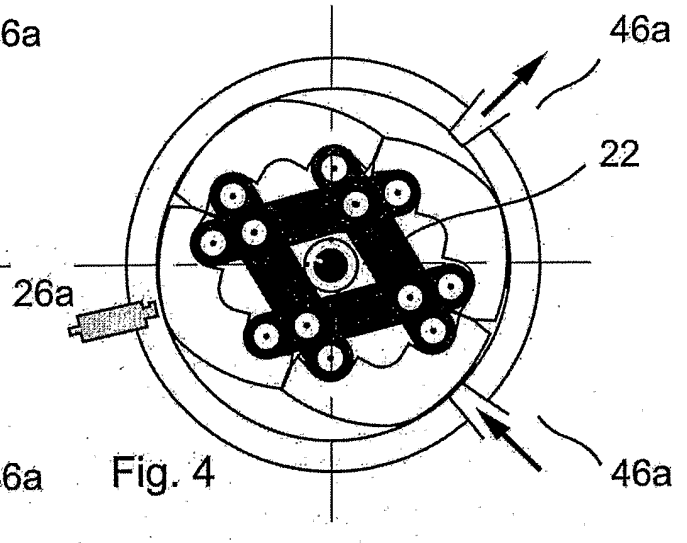
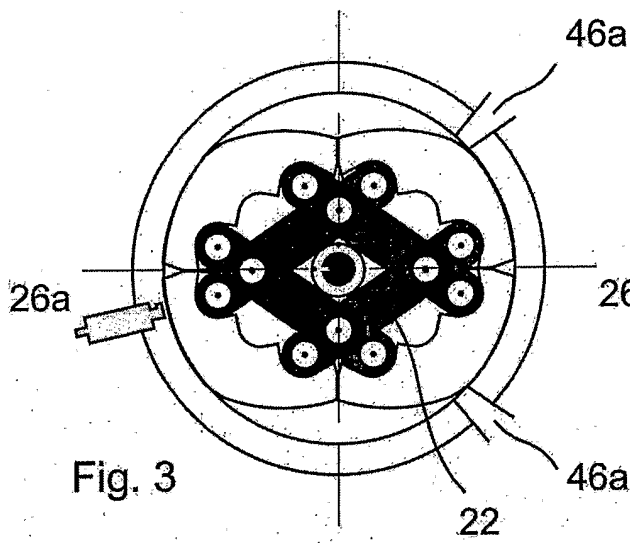
a combustion vessel for combusting compressed fuel from said first machine;

a second machine of said machines for receiving energy from combustion; and

a mechanical link between said first machine and said second machine.

68. The machine as set forth in claim 67, characterized in that said second machine is an expansion machine.





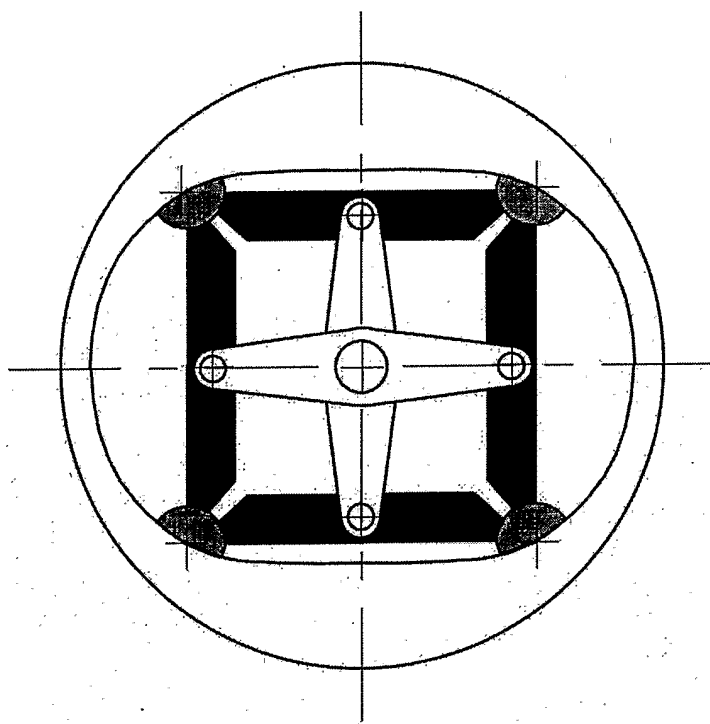


Fig. 9
Prior Art

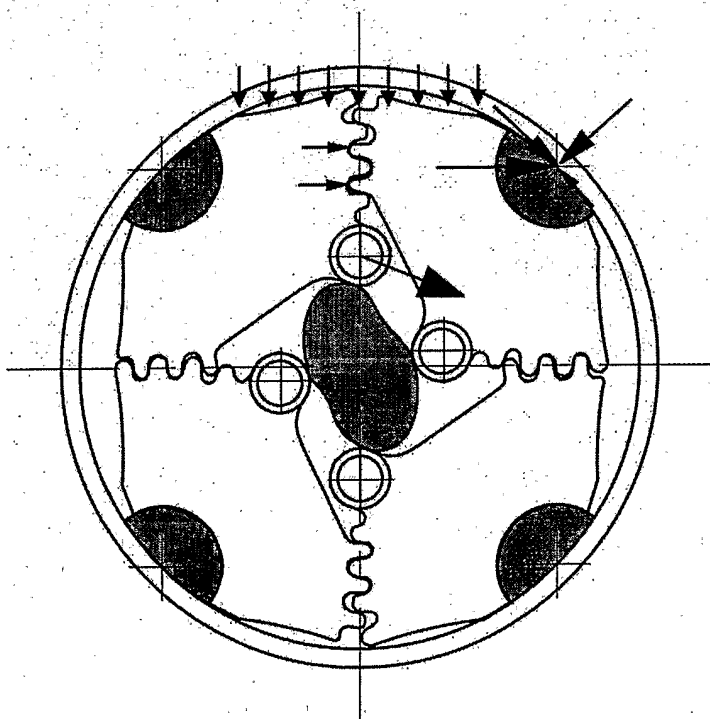


Fig. 10
Prior Art

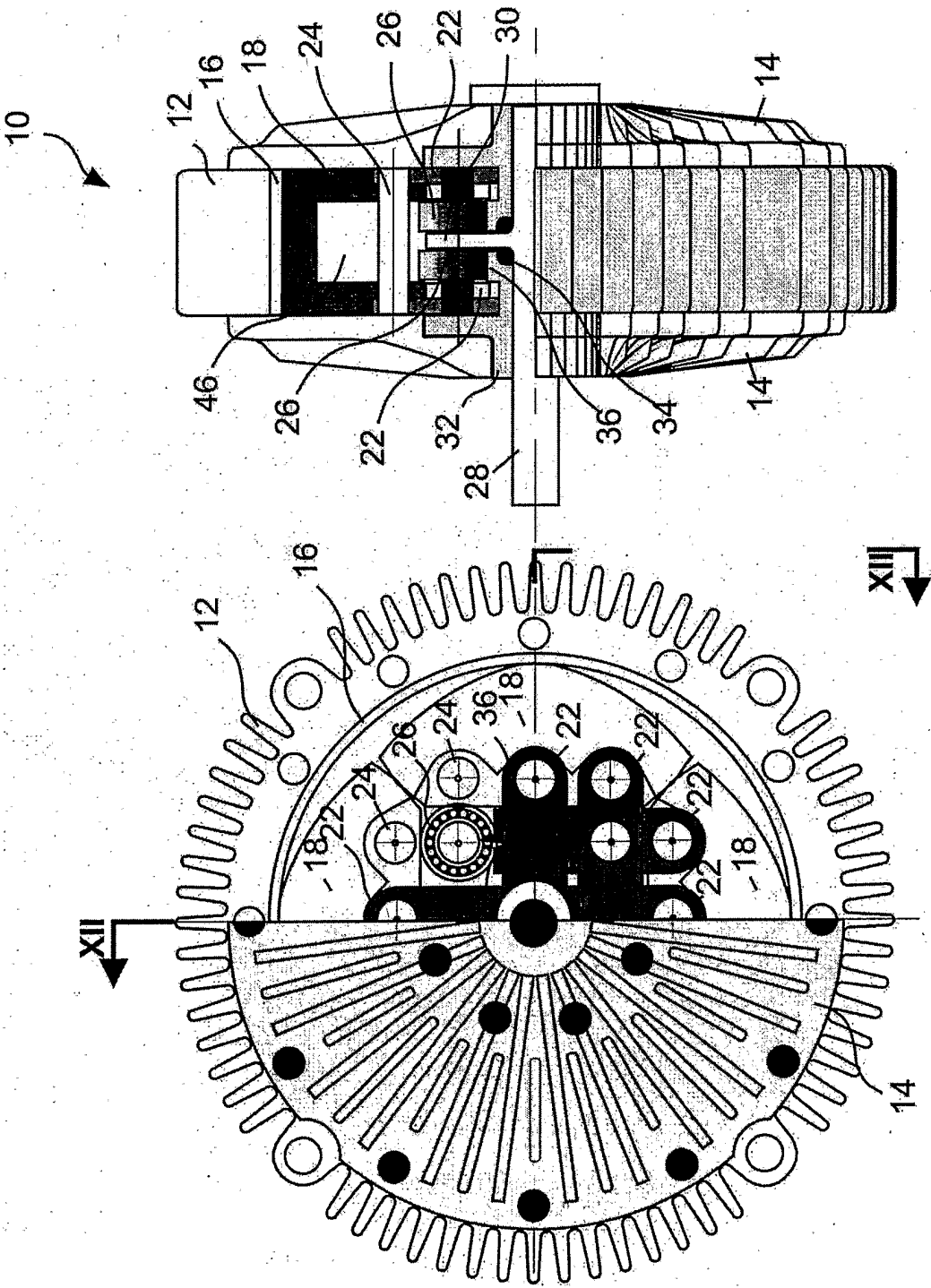


Fig. 12

Fig. 11

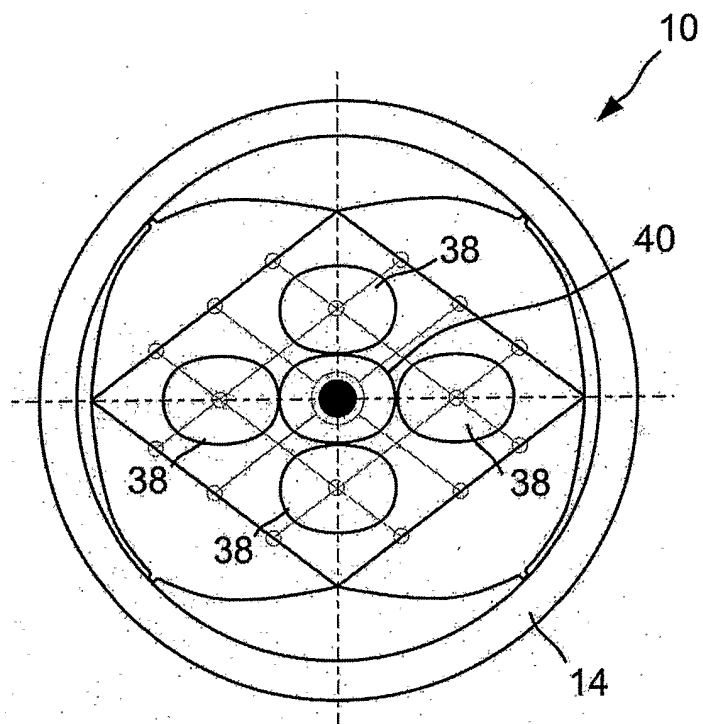


Fig. 13

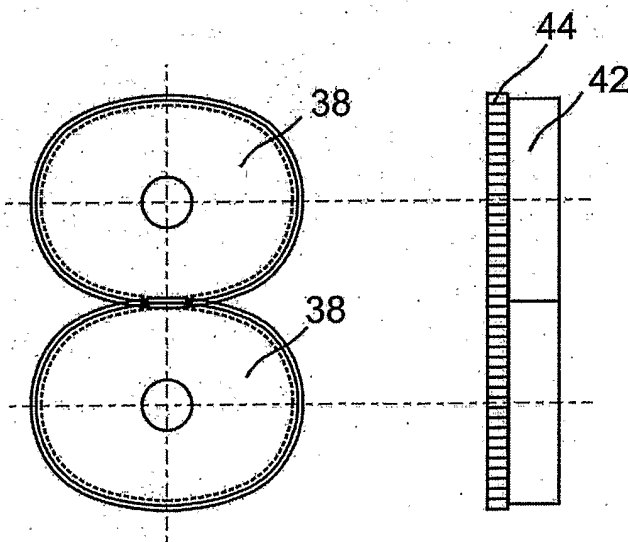


Fig. 14 A

Fig. 14 B

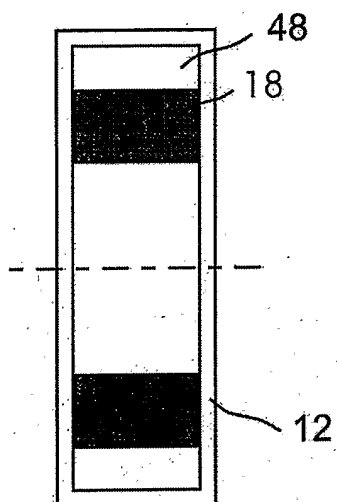


Fig. 15

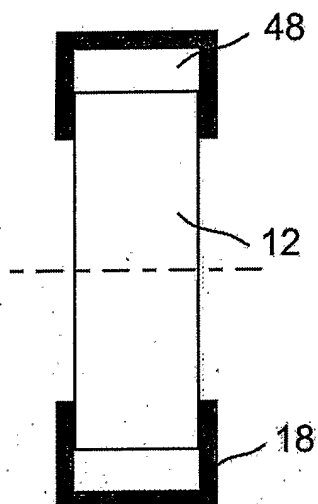


Fig. 16

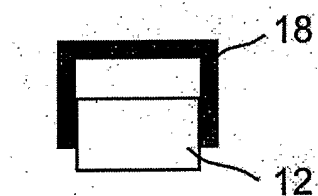
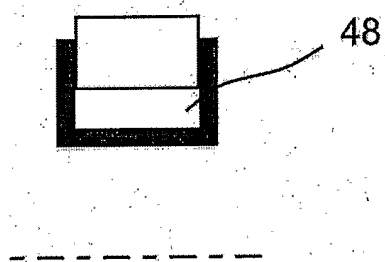


Fig. 17

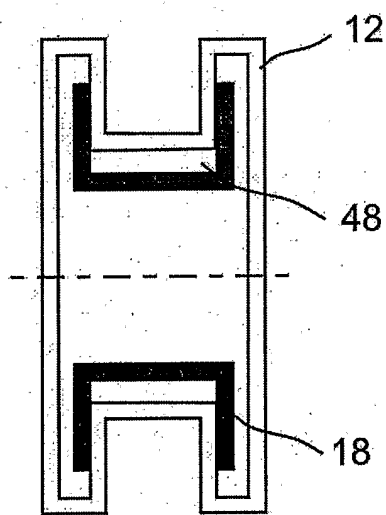


Fig. 18

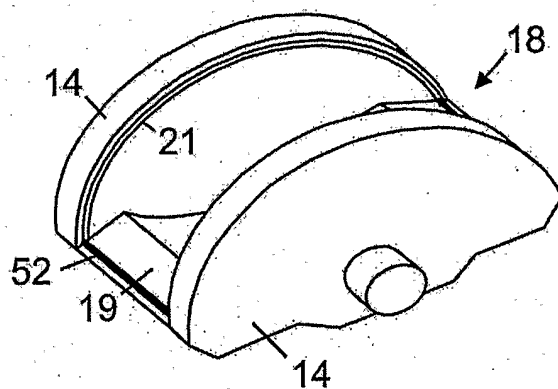


Fig. 19

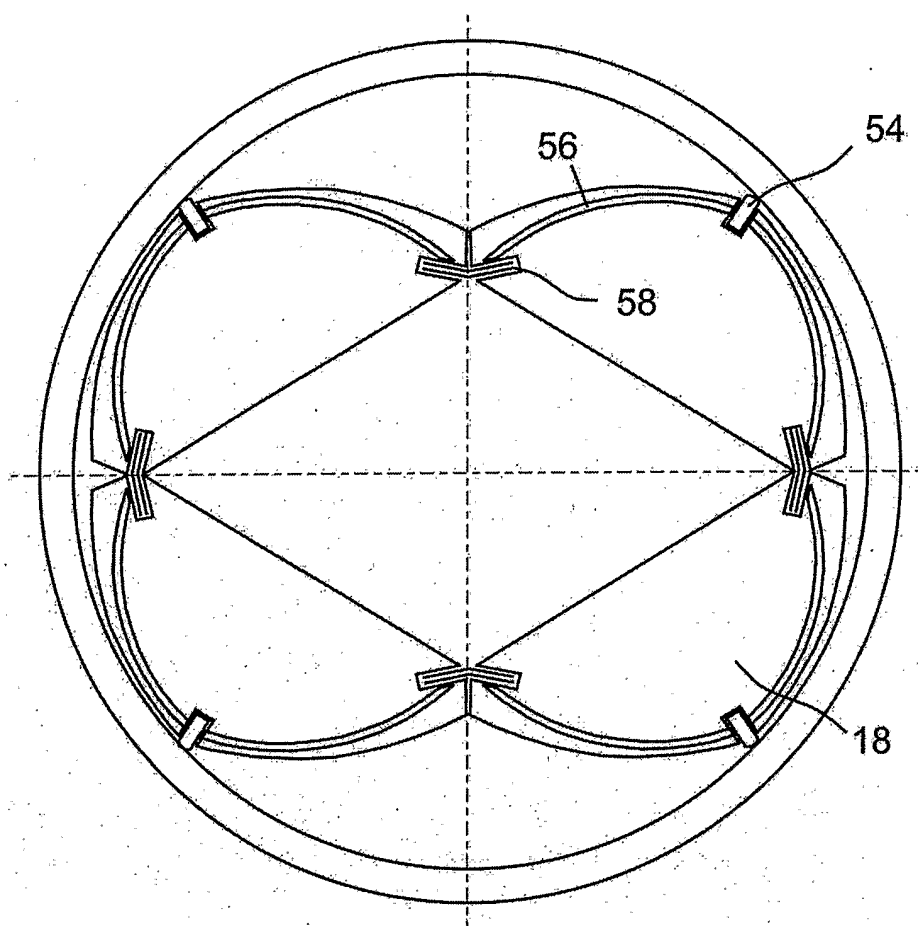


Fig. 20

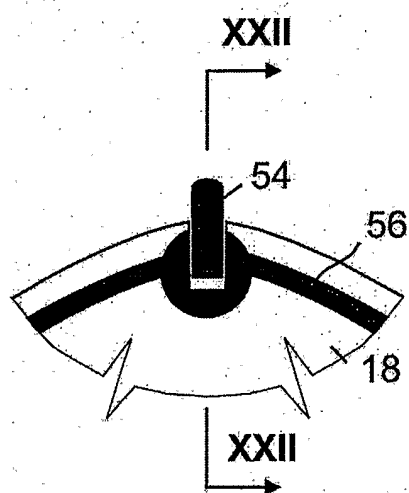


Fig. 21

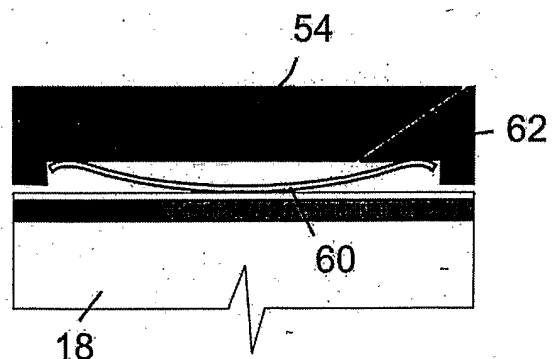


Fig. 22

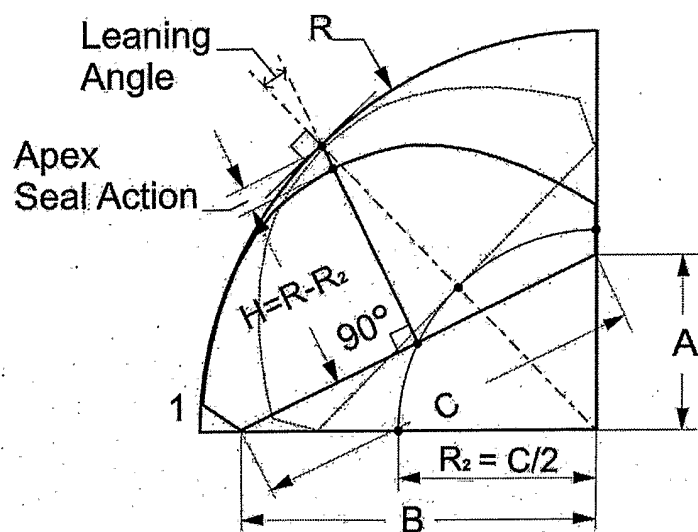


Fig. 23

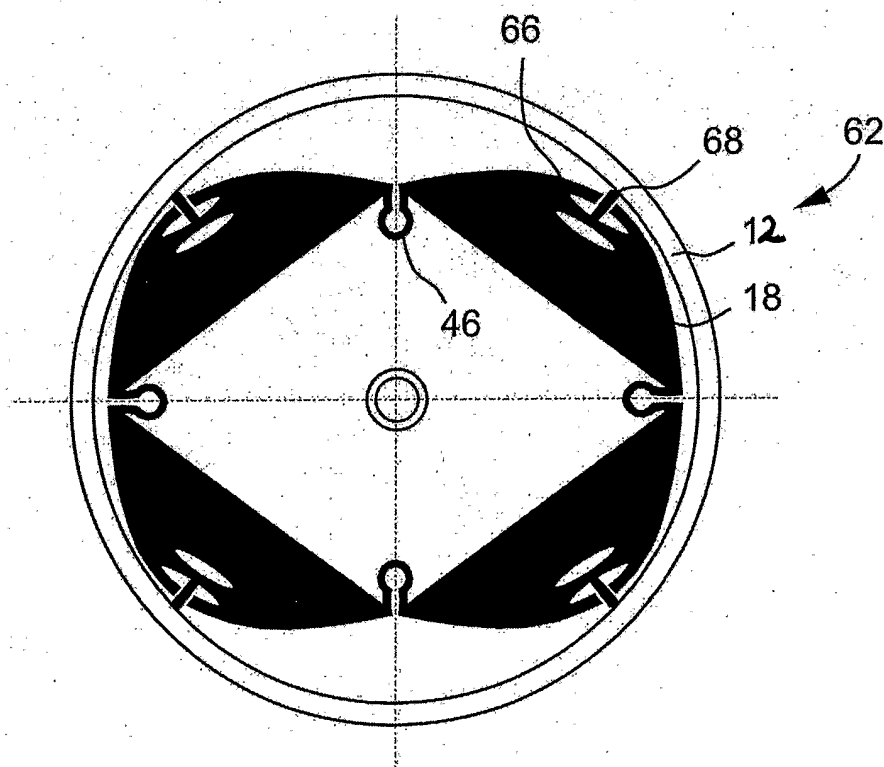
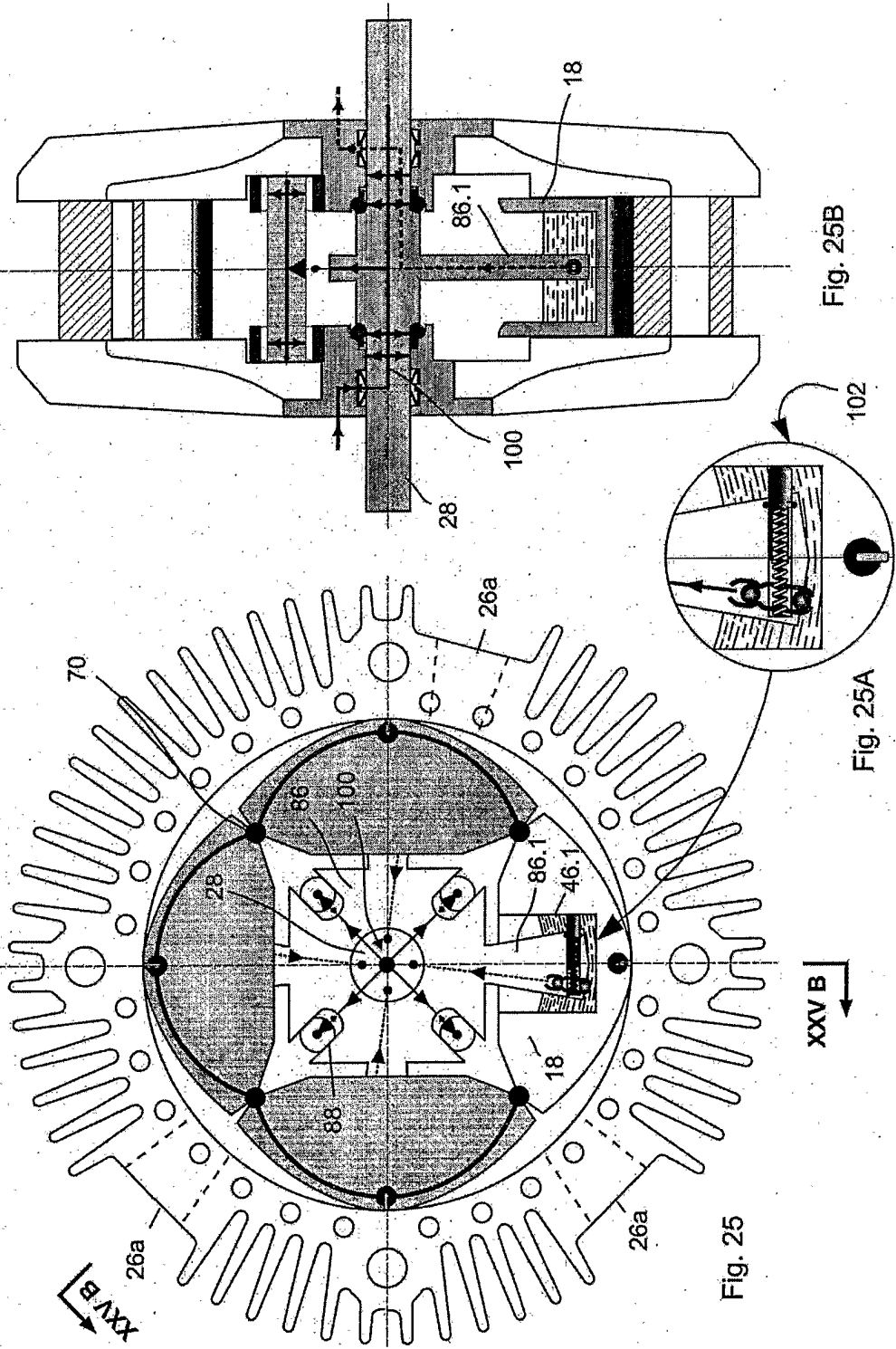


Fig. 24



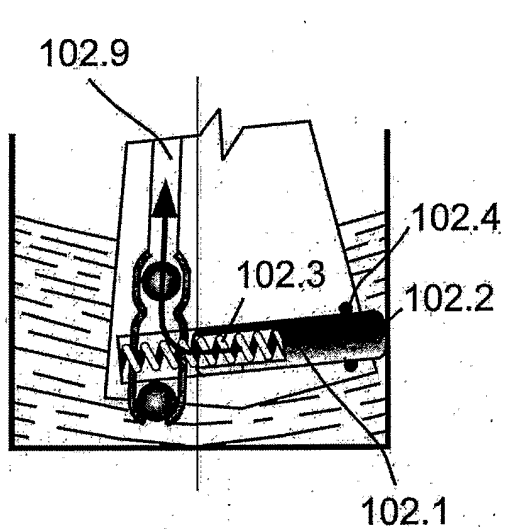


Fig. 25C

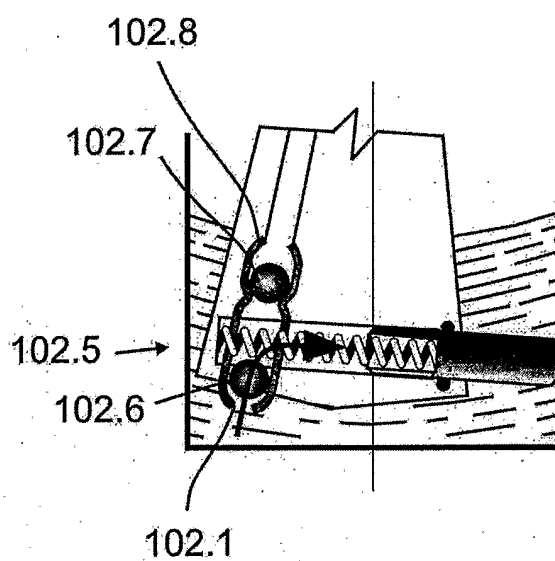


Fig. 25D

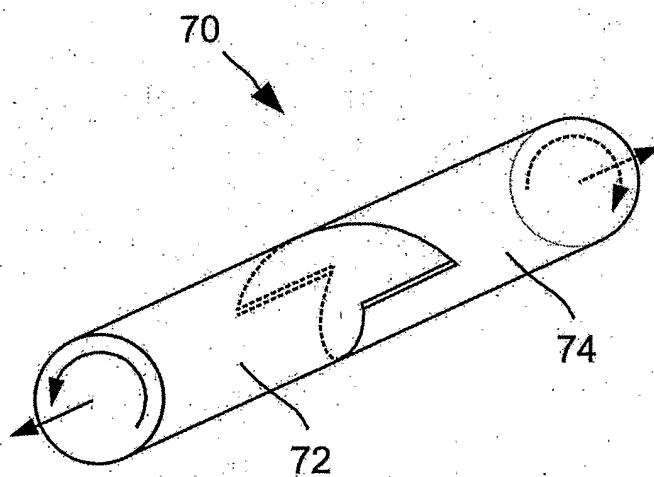


Fig. 26

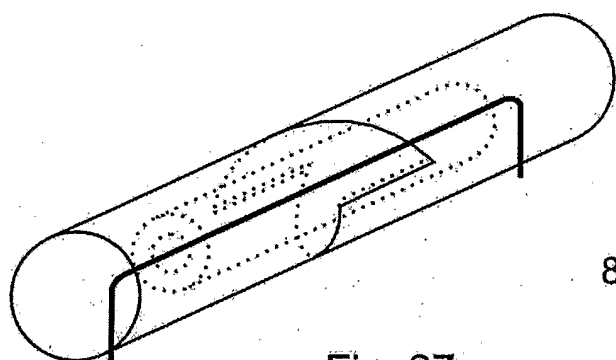


Fig. 27

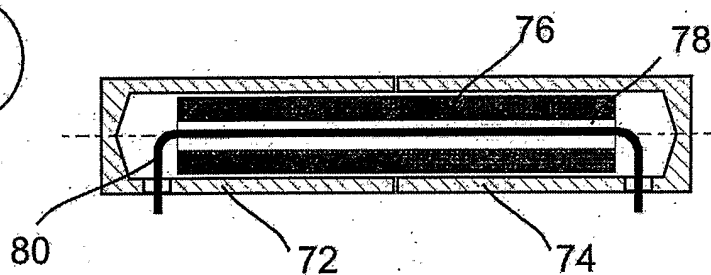


Fig. 28

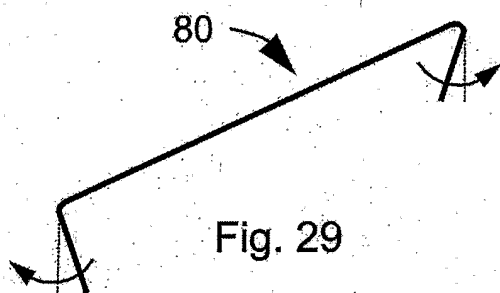


Fig. 29

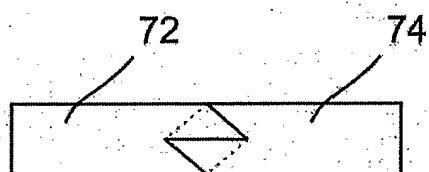


Fig. 30

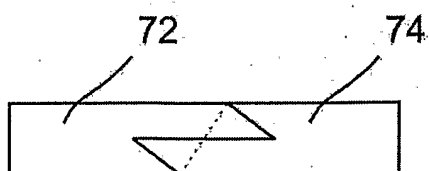


Fig. 31

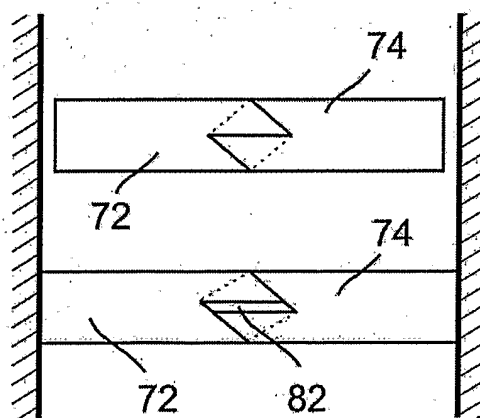


Fig. 32

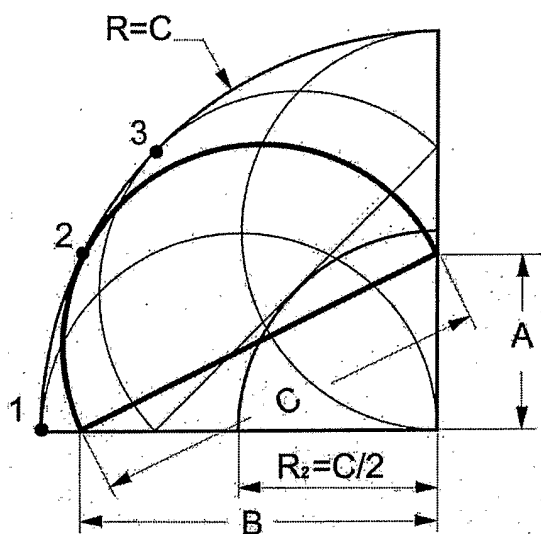


Fig. 33

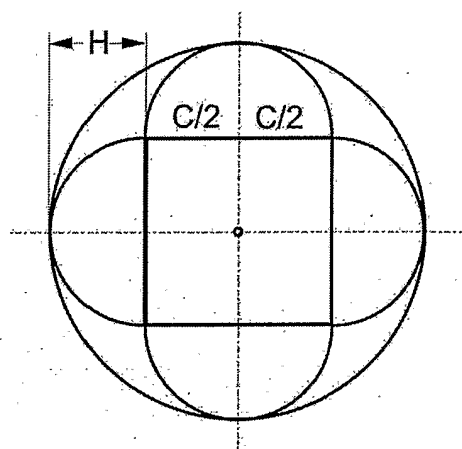


Fig. 34

$$C^2 = A^2 + B^2$$

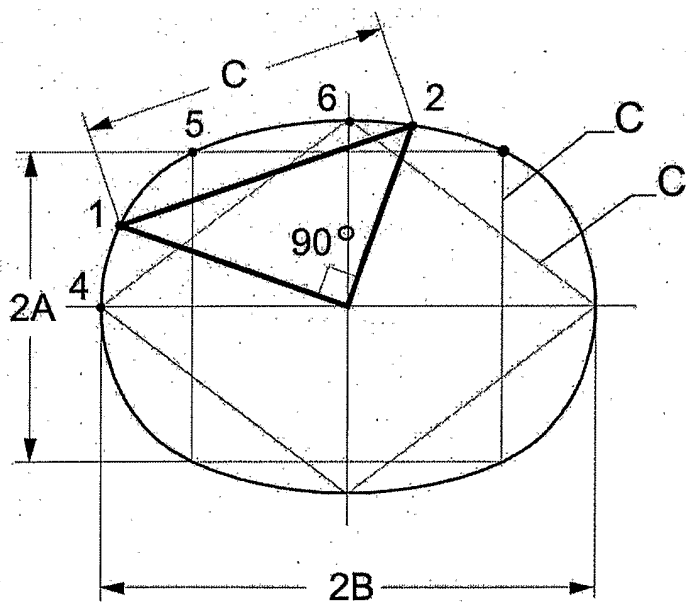


Fig. 35

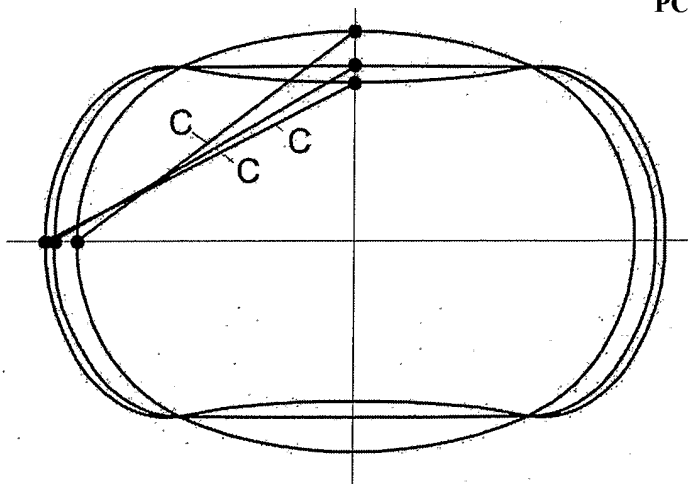


Fig. 36

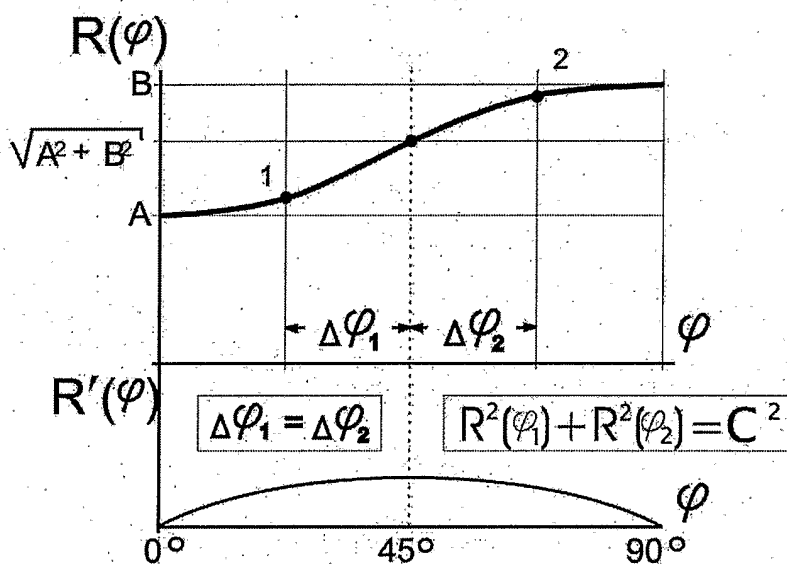


Fig. 37

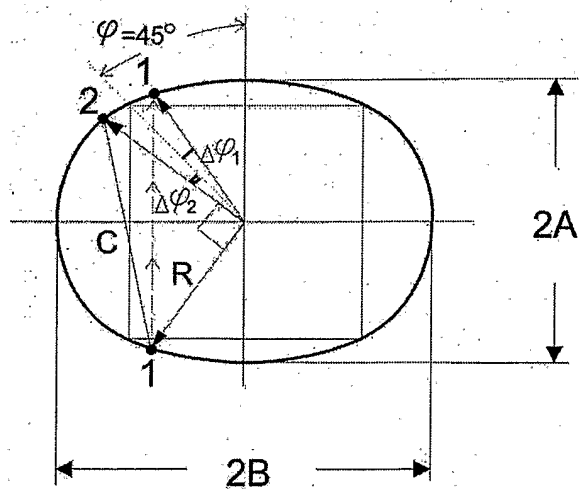


Fig. 38

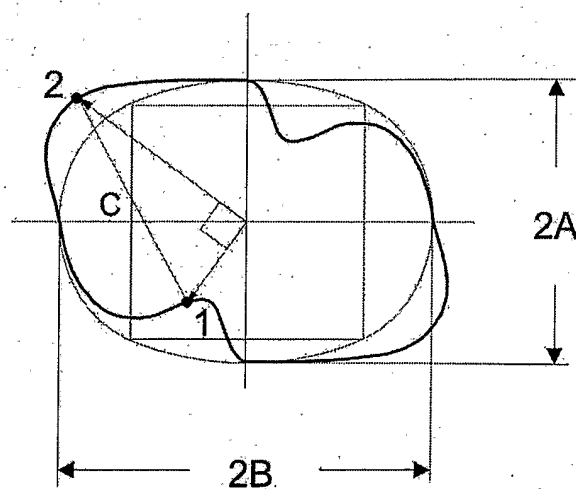


Fig. 38A

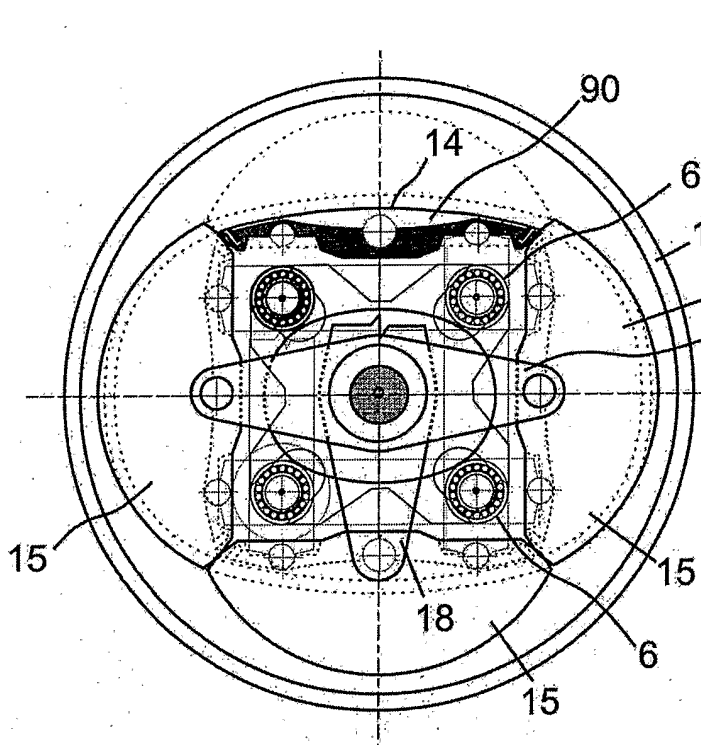


Fig. 39

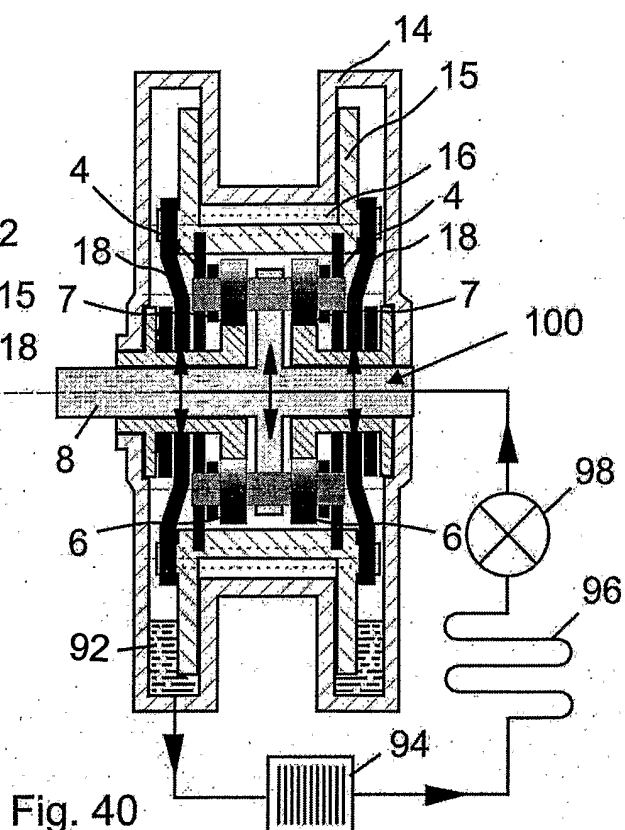


Fig. 40

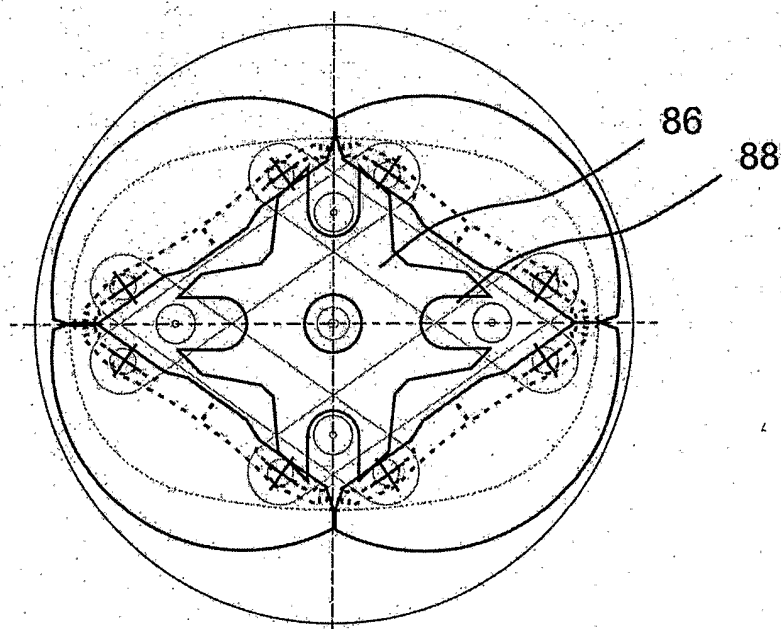


Fig. 41

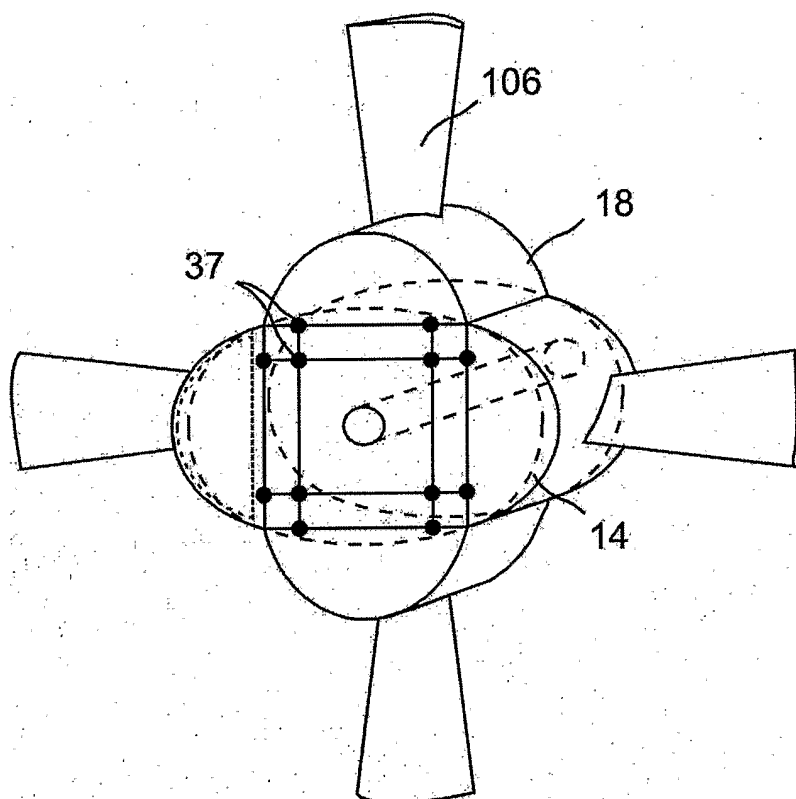


Fig. 42

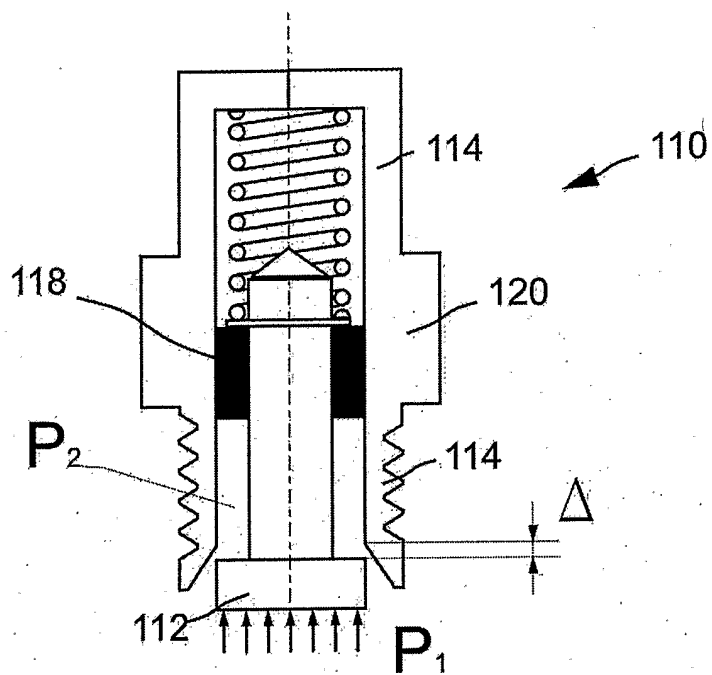


Fig. 43

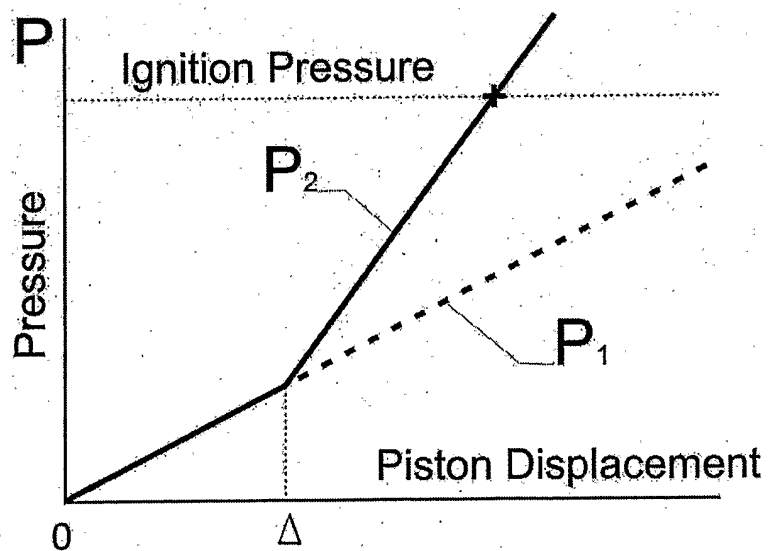


Fig. 44

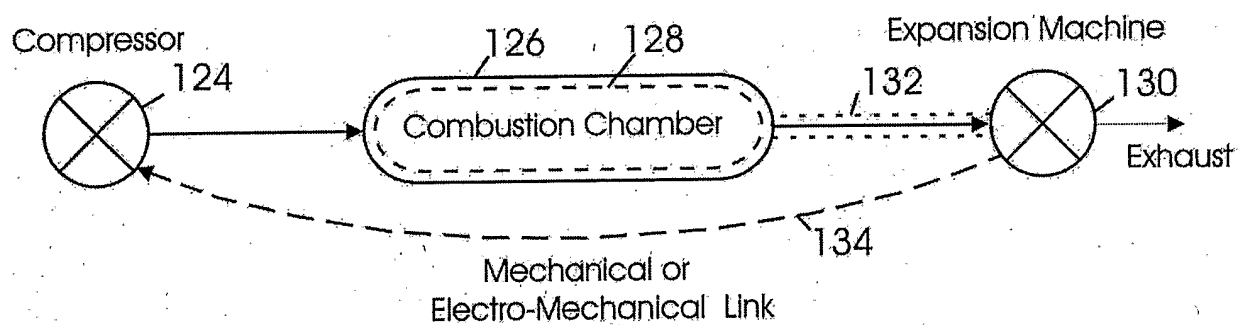


Fig. 45

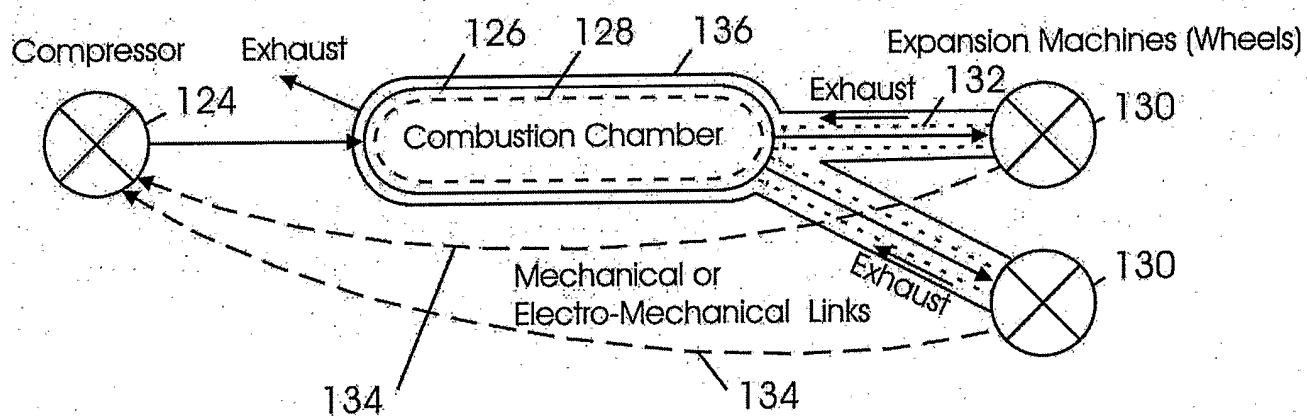


Fig. 46

INTERNATIONAL SEARCH REPORT

International Application No

PCT/CA2004/000776

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 F01C19/02 F01C1/40 F01C21/00

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)

IPC 7 F02B F01C F04C

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 practical, search terms used)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/062020 A1 (OKULOV PAUL D) 3 April 2003 (2003-04-03)	1-13, 19-31, 33,35, 43-68
Y	abstract paragraphs '0014! - '0065!, '0068! paragraphs '0075! - '0086! figures 1-40,64-96,100,102,105,112-154,160-164 -----	14,15, 36-40
Y	US 4 042 312 A (BETTS EDMUND DOUGLAS) 16 August 1977 (1977-08-16)	14,15
A	column 6, line 24 - line 63 figures 6,7 ----- -/--	16

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

° Special categories of cited documents:

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

E earlier document but published on or after the international filing date

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

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

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

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

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

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

& document member of the same patent family

Date of the actual completion of the international search

5 January 2005

Date of mailing of the international search report

12/01/2005

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Matray, J-F

INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA2004/000776

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	GB 1 057 372 A (RENAULT) 1 February 1967 (1967-02-01)	36, 38-40
A	column 3, line 48 - column 4, line 99 column 5, line 23 - column 6, line 82 figures 1-9	40-42
Y	----- DE 35 19 186 A (PAPPERT JOSEF) 4 December 1986 (1986-12-04)	36, 37
A	page 4, line 38 - page 5, line 10 figure 1 -----	18-42

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-20,43-49

Sealing between pistons

2. claims: 21-32,50-65

Elements for providing movment to the pistons

3. claims: 33-35, 66-68

Method of operation

4. claims: 36-42

Lubrification

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2004/000776

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

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

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/CA2004/000776

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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