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NOTICE OF ENTITLEMENT

I, **Pier Andrea Rigazzi**, being the applicant/Nominated Person in respect of the Application No. 21941/92 state the following :

The Nominated Person is entitled to the grant of the patent because the Nominated Person is the actual inventor of the invention.

The Nominated Person is entitled to claim priority from the application listed in the declaration under Article 8 of the PCT because the Nominated Person is the applicant in respect of the application listed in the declaration under Article 8 of the PCT, and because the application was the first application made in a Convention country in respect of the invention.

Dated this 28th day of February, 1995.



a member of the firm of
DAVIES COLLISON CAVE
for and on behalf of
the applicant(s).



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MAGNETIC DEVICE FOR CONVERTING RECIPROCATING INTO ROTATING MOTION
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- (56) Prior Art Documents
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GB 747682

(57) Claim

1. Method for moving a first member bearing a first group of permanent magnets of the same polarity along a circular trajectory by moving, by a reciprocating motion, a second member, or a plurality of second members, bearing a second group of permanent magnets and having no mechanical connection to the first member, along a rectilinear trajectory which is traverse to said circular trajectory, said first member being a magnetorotor, connected to a drive shaft and bearing the permanent magnets fixed around its outer circumference, said first member moving according to a rotative motion around an axis which is perpendicular to the plane on which the permanent magnets of said second member are radially distributed, and passes through the geometrical center of said circumference, said second member, or plurality of second members, having the permanent magnets distributed around said geometrical center, facing the first group of permanent magnets and being mechanically connected to piston(s) of an internal combustion engine, and energy restituting means being provided that are compressed by move-away motion of the pistons consequent to the gas combustion and expansion, reciprocating the motion during the return and compression phase of the engine, the method comprising effecting movement of the second group of magnets of the second member(s), by action of the energy restitution means on the piston(s), to a proximity relative to the first group of permanent magnets whereby movement of the first group

of permanent magnets toward the second group is effected by virtue of magnetic attraction therebetween, and subsequently moving the second group of magnets away from such proximity and magnetic attraction, along the same rectilinear trajectory, just before the poles mesh, as an effect of the move-away motion of the piston(s) consequent to the gas combustion and expansion.

4. Apparatus which comprises:

- (a) a first member which is a magnetorotor, bearing a first group of permanent magnets of the same polarity that are fixed around its outer circumference,
- (b) a second member, or a plurality of second members, having no mechanical connection to the first member, bearing a second group of magnets, facing the first group of permanent magnets and moving, by a reciprocating motion, along a rectilinear trajectory which is traverse to the circular trajectory of the first member, the first member rotating about an axis which is perpendicular to the plane on which the permanent magnets of the second member, or a plurality of second members, are radially distributed and passes through the geometrical center of said circumference, said first member being connected to a drive shaft;
- (c) an internal combustion engine with a combustion chamber;
- (d) energy restituting means that are compressed during the move-away motion of piston(s) of the engine, after the gas combustion and expansion and reciprocate the motion during the return and compression phase of the engine cycle;

wherein said first group of permanent magnets faces said second group of permanent magnets with opposing polarity, the second member moving the first member as a result of the magnetic attraction between said two groups of permanent magnets, and said internal combustion engine has its combustion chamber directed toward the said geometrical center, said second group of magnets of the second member(s) moving the first member by entering the field of magnetic interaction with said first group of permanent magnets as an effect of the action of the energy restituting means on piston(s) that are coupled thereto and subsequently being moved away from the first group of magnets, along the same rectilinear trajectory, just before poles of the groups of magnets mesh, as an effect of the move-away motion of the piston(s) consequent to the gas combustion and expansion.



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(21) International Application Number: PCT/EP92/01462 (22) International Filing Date: 29 June 1992 (29.06.92) (30) Priority data: 1978/91-4 3 July 1991 (03.07.91) CH (71)(72) Applicant and Inventor: RIGAZZI, Pier, Andrea [IT/CH]; Contrada San Marco, CH-6982 Agno (CH). (74) Agent: FIAMMENGHI-FIAMMENGHI; Via San Gotardo, 15, CH-6900 Lugano (CH). (81) Designated States: AT, AU, BB, BG, BR, CA, CH, CS, DE, DK, ES, FI, GB, HU, JP, KP, KR, LK, LU, MG, MN, MW, NL, NO, PL, RO, RU, SD, SE, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IT, LU, MC, NL, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, SN, TD, TG).		Published <i>With international search report.</i> 66 1 0 0 9
(54) Title: MAGNETIC DEVICE FOR CONVERTING RECIPROCATING INTO ROTATING MOTION		
(57) Abstract The method allows to move, for example with a rotative motion, a member or a group of members by moving another member or group of members with a reciprocating rectilinear motion by means of the interaction between magnets (1, 2, or groups of magnets (1i, 2i) fixed to the said members or group of members. If the reciprocating rectilinear motion is obtained by connecting one of the two groups of magnets to the pistons of a reversed-star two stroke engine and to a mechanical energy restituting system (8), a high-efficiency propulsing means is realized, which is suitable for engine-traction, which does not need a crank-shaft, a lubricating system, water cooling system, alternator or torque converter, and is automatically switched off when the vehicle is not in motion. Its work-torque can be varied by varying the distance between said restituting system (8) and members (14) named cursors, connected to pistons (5). Easy and cheap to make, it causes little-pollution and is suitable even for using hydrogen as fuel. In which case, its pollution products are insignificant or equal to zero.		

The present invention relates to a method for moving a group of members along a trajectory by moving a second group of members with a reciprocating motion along another trajectory by means of the magnetic field interaction of permanent magnets fixed
5 on the members, and apparatuses for realizing the method.

The subject of the present invention is based on studies of dynamics of magnetized elements and may have several different applications e.g. for car engines, for industrial vehicles engines, more generally for propulsion and, for example, for electrical current
10 generators.

In accordance with the present invention, there is provided a method for moving a first member bearing a first group of permanent magnets of the same polarity along a circular trajectory by moving, by a reciprocating motion, a second member, or a plurality of
15 second members, bearing a second group of permanent magnets and having no mechanical connection to the first member, along a rectilinear trajectory which is traverse to said circular trajectory, said first member being a magnetorotor, connected to a drive shaft and bearing the permanent magnets fixed around its outer circumference, said first member moving according to a rotative motion around an axis which is
20 perpendicular to the plane on which the permanent magnets of said second member are radially distributed, and passes through the geometrical center of said circumference, said second member, or plurality of second members, having the permanent magnets distributed around said geometrical center, facing the first group of permanent magnets and being mechanically connected to piston(s) of an internal combustion engine, and
25 energy restituting means being provided that are compressed by move-away motion of the pistons consequent to the gas combustion and expansion, reciprocating the motion during the return and compression phase of the engine, the method comprising effecting movement of the second group of magnets of the second member(s), by action of the energy restitution means on the piston(s), to a proximity relative to the first group of
30 permanent magnets whereby movement of the first group of permanent magnets toward the second group is affected by virtue of magnetic attraction therebetween, and subsequently moving the second group of magnets away from such proximity and magnetic attraction, along the same rectilinear trajectory, just before the poles mesh, as



an effect of the move-away motion of the piston(s) consequent to the gas combustion and expansion.

In another aspect, there is provided an apparatus which comprises:

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- (a) a first member which is a magnetorotor, bearing a first group of permanent magnets of the same polarity that are fixed around its outer circumference,
- (b) a second member, or a plurality of second members, having no mechanical connection to the first member, bearing a second group of magnets, facing the first group of permanent magnets and moving, by a reciprocating motion, along a rectilinear trajectory which is traverse to the circular trajectory of the first member, the first member rotating about an axis which is perpendicular to the plane on which the permanent magnets of the second member, or a plurality of second members, are radially distributed and passes through the geometrical center of said circumference, said first member being connected to a drive shaft;
- (c) an internal combustion engine with a combustion chamber;
- (d) energy restituting means that are compressed during the move-away motion of piston(s) of the engine, after the gas combustion and expansion and reciprocate the motion during the return and compression phase of the engine cycle;

wherein said first group of permanent magnets faces said second group of permanent magnets with opposing polarity, the second member moving the first member as a result of the magnetic attraction between said two groups of permanent magnets, and said internal combustion engine has its combustion chamber directed toward the said geometrical center, said second group of magnets of the second member(s) moving the first member by entering the field of magnetic interaction with said first group of permanent magnets as an effect of the action of the energy restituting means on piston(s) that are coupled thereto and subsequently being moved away from the first group of magnets, along the same rectilinear trajectory, just before poles of the groups of magnets mesh, as an effect of the move-away motion of the piston(s) consequent to the gas



combustion and expansion.

Naturally the magnets, for a long lasting efficiency, should be "stabilized", and their temperature kept by suitable means under a preset limit dependent on their constitution.

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A method similar to the above is disclosed in Patent Application EP-A-0 152 252, but disposition and motion of the various parts is different, and repulsive magnets are used, thereby making it difficult to achieve the same results offered by the present invention, especially as far as the mechanical efficiency rate is concerned.

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A further method is described in Patent No. US-A-3 992 132, wherein magnets are used for converting a rotative motion into a reciprocating motion but, given the way the parts are mounted and the arrangement of the magnets (with alternated polarities), such a method is not suitable for effecting the opposite conversion of a reciprocating motion
15 into a rotative motion.

The invention will now be more fully described, by way of non-limiting example only, with reference to the accompanying drawings in which:

20 - in fig. 1a, 1b, 1c, 1d a sequence of positions of two members fixed on two magnets, during the motion obtained by means of the method of the invention;

- in fig. 2 the method is applied to two groups of magnets, one of which is fixed on an external circumference of a rotating cylinder, made from a non-magnetic material;

5 - in fig. 3 the cross-section of an embodiment adapted to realize the method of the invention with connection to a pair of "reversed star" six cylinder engines;

10 - in fig. 4 a further embodiment with a one star engine and double cylinder;

- in fig. 5 a schematic drawing of a further possible embodiment, with one engine and a triple rotating cylinder;

15 - in fig. 6 a possible way of suitably laying and orienting the magnets which are fixed to the members forming the apparatus of the invention, coupled to a reversed star 6 cylinder engine;

20 - in fig. 7 a schematic drawing, concerning only one magnet, reciprocated by one piston, one magnet of the first rotating cylinder and one magnet of a second rotating cylinder integral to the first one;

25 - in fig. 8 a sketch explaining the balanced distribution of forces for simultaneous explosions in four cylinders;

- in fig. 9 the schematic top view of an apparatus coupled to a six cylinder engine with the cylinders axes inclined with respect to the outer surface of magnets 1ⁱ of the rotating cylinder (magnetorotor);

30 - in fig. 10 a section of the engine effected along a plane parallel to the sheet of the drawing and comprising the axis of a piston, or pulsor: to show the parts more clearly a scavenging-air compression cylinder has also been represented, although it is located below the plane;

35 - in fig. 11, the particular path suggested for the pressurized scavenging-air;

- in fig. 12 a detail representing the combustion and ignition area;
- in fig. 13 a prospective view of an engine with as many cylinders as magnets located along a circumference of the magnetorotor;

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- in fig. 14 the engine interposed between two overlaid magnetorotors;
- in fig. 15 two engines mechanically connected "in series" by means of a motion-inverter;

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- in fig. 16 the curve of the trajectories followed by the center of a magnet or of a ferromagnetic member moving integrally with a pulsor, with respect to the magnetorotor;

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- in fig. 17 the side-view of a longitudinal section of the mechanical energy restituting system, with variable distance between springs and a fixed structure, according to one embodiment of the invention;

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- in fig. 18 the trajectories, which may be achieved, with and without the above said energy restituting system, respectively.

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With reference to figures 1a, 1b, 1c, 1d: from physics it is known that magnetic fields are irrotational, i.e., in this case, that the energy supplied or "absorbed" by the magnetic field from two ferro-magnetic objects, of which at least one is magnetized, during any movement along a closed line inside said field is equal to zero, (this being valid also if said line closes at the infinite).

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Magnetized members 1 and 2 (which are allowed to move only along lines x and y respectively) because of their mutual attraction, will lose, during their simultaneous movements from A to U and from B to O, an amount of potential energy exactly equal to the energy that an external force shall supply for example to member 2 in order to pull it back over the extreme border limit of the magnetic field.

In other words in fig. 1a, if magnets 1 and 2, which may only move along line x and y,



respectively, are brought to a distance small enough for their mutual attraction to be initiated, they attract one another because of the related magnetic field, and are accelerated along line y and line x, respectively, acquiring kinetic energy and reaching the positions shown in fig. 1b; at this point, i.e. immediately before their magnetic axes
5 w and z lay one over the other and their poles mesh, if the magnet 2 is suddenly pulled back vertically, by an external force F along line y, so that the poles are very quickly separated before the braking action, which magnet 2 would effect on magnet 1 occurs, if the latter would keep moving while they still were located at the position of poles-meshing, it will be achieved that magnet 1 and a member eventually fixed to it, will be
10 able to keep on running along line x, with the kinetic energy that they had acquired up to that moment (fig. 1d).

Naturally the sequence described above may be repeated indefinitely, with other magnets 1ⁱ entering the field of magnetic attraction at the same time as a spring 8 or a similar
15 energy restituting device returns magnet 2.

Then, if magnets 1ⁱ which are contiguous or equally interspaced, are fixed along the outer circumference of a cylinder 3 (obviously made from non-magnetic material), as shown in fig. 2, and a certain number of magnets 2ⁱ are positioned radially around said
20 cylinder, all of them being provided with an energy restituting system 8, as previously disclosed, it will be possible by suitably timing the action of forces F upon each magnet 2, to move the magnetorotor, i.e. the rotating cylinder 3, with a rotative motion due to the pulling action on said cylinder operated by magnets 1ⁱ.

25 The concept is still totally valid if many groups of magnets 1ⁱ and 2ⁱ are stacked (one upon another) as shown in figures 3 and 4.

In order to exert forces F on magnets 2ⁱ, it is for example possible to mechanically connect them to the pistons of one or more than one "reversed star" internal combustion, preferably two-stroke engines 6, 6', obtaining the result of transforming the energy
30 supplied by the combustion into kinetic energy, actually mechanical energy of the magnetorotor 3, and of a drive shaft 7 rigidly connected thereto.



The energy supplied by each combustion exceeding the work drawn magnetorotor 3 will be restituted to the piston by energy restitution devices, such as, for example, springs 8 and, as better explained later, it will cooperate to effect the compression inside the cylinder for the following cycle.

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In order to reduce the volume of the device for a given power, it is useful to arrange the magnets adjacent one another along each circumference and, for making that possible, without the action of each magnet negatively interfering with the action of another adjacent, it is useful to foresee a suitable aiming of the vector of magnetic field of the magnets, installing also flux baffles 13 made from metal sheet and shaped for example as shown in figure 6, on said magnets.

Figure 6 shows a possible example of such a way of positioning the magnets, which will be further described below, with the axis of the magnetic field inclined by a desired angle with respect to the faces of the magnets, in order to correct the little scalar trajectory aberrations owing to the curvature of the parts. The magnetic flux baffles 13 have a wall parallel to this axis, the direction of which is substantially parallel to the trajectory of the relative motion of the magnets moved by reciprocating motion with respect to the magnetorotor magnets during the approach stroke.

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The axes of motion of pistons 5ⁱ, in a preferred embodiment, are substantially parallel to the axes of the magnetic fields of magnets 1ⁱ (fig. 9) or more generally not perpendicular to the outer face of the magnetorotor.

25 It is to be pointed out that said flux baffles 13, among other things, increase the induction linked to the single magnets in an area most effective for the working of the apparatus, practically eliminating it in the remaining areas, therefore their use is oft advisable. The same figure 6 shows a



further improved embodiment of the apparatus: by means of suitable linking parts 14, many contiguous magnets are connected to one piston. For example, in the case of a 6 cylinder engine, their number is equal to 1/6 of the total number of the magnets installed along a single circumference of rotor 3.

Many rows (10 in figure 4), carrying the said number of magnets may be stacked upon one another. If 42 magnets are installed along a circumference of the rotor, for example, each piston is connected to $42/6 \times 10 = 70$ magnets, allowing the use of the energy supplied by the combustion inside the related cylinder.

The form, induction, number and dimensions of the magnets may be varied, and there are several possible ways of aiming the fields and positioning the magnets on the various parts; the most useful solutions will be described, case by case, by the test-work.

For constructing magnetorotors and more generally components which move within the various magnetic fields it is naturally necessary to choose non-magnetic materials, with good mechanical resistance.

Such an embodiment as a propeller coupled to one or to more than one internal combustion engines is advantageous also as far as the efficiency is concerned. In order to understand this, it will be useful to consider the energy balance of the apparatus, referring, for an easier comprehension, to only one pair of magnets 1, 2, as shown in figure 2.

It has to be firstly considered that, given the features of the apparatus, the amount of energy lost because of friction effect is extremely low.

As mentioned, the potential energy of the two magnets, during their mutual approach due to mutual attraction, becomes kinetic energy of both magnets, but however the kinetic energy of magnet 1 alone makes rotor 3 rotate.

5 The kinetic energy of magnet 2, though, if connected, as shown, to a piston of an internal combustion engine, is not wasted, as it becomes, during the pistons return stroke, compression work of the gas, as already mentioned, inside the cylinder before the next ignition, cooperating with the energy-restituting device 8.

The curve of the magnetic attraction force related to the distance is, however, similar to the curve of a "pseudoadiabatic" compression.

10 In order to achieve the maximum efficiency of the apparatus, a suitable way to go is to electronically relate, by means of well known methods and devices, the injection and ignition timing to the positions of magnets 2 (or also of the members fixed thereto) with respect to the rotating cylinder, to its rotation speed, to the amount of injected fuel, or to all these factors together, or to others depending on type and way of working of the used electronic control device.

15 By so doing, the result is obtained that move-away- and return-stroke of magnets 2ⁱ correspond to a predetermined rotation angle of magnetorotor 3 and that predetermined trajectories are followed in order to get the most proper work-cycle of the magnets.

20 For purposes better explained in the following parts of the description, the electronic control system might also take into account the motion of an operating device (also better explained later on) operated by a driver, device that "activates" a given number of pistons.

25 Further, and for similar reasons, it is useful to regulate the injected amount of fuel at the same time, relating it to the rotation speed of magnetorotor 3.

30 A stopping device, for example a stiff ring 23 (fig. 3) stops magnets 2ⁱ from touching magnets 1ⁱ if an accidental compression failure inside a cylinder occurs.

35 Considering the description to this point, it is clear that a propeller derived from the method which is the subject of the invention does not require a crank-shaft or linking rods. Hence, it will be possible, by

means of the afore mentioned driver operated devices, connected to an electronic control box of known type, to cause both injection and ignition in some or all of the cylinders, depending on the power or torque to be supplied. If then it is preferable (subject to worsening the noise level) to fully eliminate the strains (already very small, given the low speed and the fractioning of the cylinder) radially acting on bearing 16, 16' of drive shaft 7 connected to the magnetorotor, it is possible in one embodiment, to foresee that, for example in a six-cylinder star, engine, for five different positions of the driver operated device (i.e. a pedal), injection and ignition occur in none, two, three, four or 6 cylinders, geometrically positioned in such a way that the resulting force produced by the radial components acting on the pistons, and its resulting torque around the rotation axis are at any time equal to zero (fig. 8). The higher the number of pistons, the "smoother" the apparatus will work. As already mentioned, the axis of pistons 5ⁱ are not necessarily perpendicular to the surface of the magnetorotor 3. A possible solution foresees axes inclined with respect to the outer surfaces of magnets 1ⁱ (fig. 9) fixed on magnetorotor 3. For normal appliances, such as car-engines, it may be advisable to interconnect all the pistons, mechanically and/or connecting the various combustion chambers so as to get an exact and easier synchronization among them, notwithstanding the slight differences of, for example, the mechanical loss due to friction effect related to the various pistons. In such case, all the pistons would work the same way and contemporarily. By carefully dimensioning (for example by means of drive ball bushings 21) the driving with the lowest possible friction of magnets 2ⁱ, or more properly of the parts (11) supporting them, and their linking system 22 to pistons 5 (for example a sphere-point 22' in figure 4), it is easy to reach the result that the forces effected on said pistons by the group of magnets 2ⁱ linked to them do not have any component cutting the axes of the cylinders, as they are purely axial, and this considerably limites friction and over-heating on the cylinder walls (due in this case only to the pressure of the compression pressure seal-rings), significantly or totally reducing the need of lubricating said cylinders, the need for oil-whipping etc, with evident economical and



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enviromental advantages. To start the apparatus, given its features, it is sufficient to let the magnetorotor rotate a small angle up to the meshing of reference points, for example installed on the rotor and on a non-rotating part, respectively, which the electronic control-box uses to perform its functions. After the first combustion, the apparatus will run automatically. The said reference points are not shown in the figures. For the starting operation it is possible to use well known means, such as a "gear-box" type lever with reduction gear, or a belt and free-wheel device, connected to the rotor or other similar solutions, not shown in the figures. In the stand-by situation (with the vehicle not in motion or even just with the aforementioned pedal at a position 0 in the case of motor vehicles), the propeller is inactive and no combustion occurs.

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In order to generate the charge-current for the batteries of the vehicle carrying the device according to the invention, it is sufficient to fix one or more magnets 10 to one or more members moved by reciprocating motion (one of these members shown in fig. 4 is a shaft 11 mounted on supporting member 14 also called cursor, of magnets 2¹) and to mount one or more members 12 on one or many parts of the fixed structure 20, said parts being able to transform the energy produced by the reciprocated mutual approaching and separating motion of said magnets 10 into electric current. Said members may be simple induction-coils, on whose end-contacts an alternate voltage will be drawn, a voltage that, when rectified by means of known methods, can generate the charge-current of said battery or batteries.

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It is also possible with the low values of magnetic induction linked to each single magnet, since its variation is very quick, and therefore relevant to the voltage $e = - \frac{d\phi}{dt}$ at the end contacts of mentioned coils.

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A preferred embodiment shows the use of relatively large diameter pistons (pulsors) with a limited compression strokes which are shorter than the distance between two facing magnets when on the border-line of the sensible attraction field.

The disclosed propeller is applicable in many cases; e.g.: for propulsion purposes on cars, agriculture, transportation and industrial vehicles, coupled to the rotor of helicopters and, more generally, as propeller for a rotating shaft, for example the shaft of a motor-operated current generator.

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There are considerable advantages offered by the method of the invention and by the propeller derived therefrom for example in the field of motor-vehicles, they eliminate the need for many costly devices traditionally coupled to an internal combustion engine, such as:

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crank-shaft with related supports and bushings;

linking-rods with related supports, pins, bushing etc.;

15 fly-wheel: the magnetorotor, suitably dimensioned is a fly-wheel "per se";

gear-box: since at any rotation speed the torque can be varied by activating or deactivating a determined number of pistons, or by regulating the energy per cycle, and/or by varying the distance between springs 8 and cursors 14, it may be sufficient to have a simple gear box for forwards and backwards motion, or a gear box with fewer gears than traditional gear-boxes;

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the starting-

25 motor: the starting operation can be done manually as described;

the alternate or direct current generator for charging the battery;

the torque converter for the heavy duty vehicles;

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the device, recently developed and realized, for automatically switching off the engine when the vehicle is not in motion;



the lubricating system for the pistons and for the engine as a whole;

the cooling-system: with star engines, given the low temperatures and the dimensions of the heat-exchanging surface, and given the empty space inside the magnetorotor, a helicoidal profile 18 fig. 4 mounted therein, or fins 19 fig. 3 similarly located can convey sufficient air throughout holes 3" formed on the "lids" of the rotating cylinder 3 for a sufficient cooling-down. Also said lids, if suitably shaped, can work as cooling ventilator 3' fig. 3.

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The resulting specific fuel consumption is very low, as will be explained later.

The total weight of the propeller and of all the essential parts is considerably reduced, with all the attained advantages and especially during city-use, owing to the high value of the air/fuel ratio and the relatively low adoptable working temperatures, pollution can be significantly reduced.

In addition, the assembly time and the number of parts used is minimal, which could considerably reduce the costs of a motor-vehicle, or make it possible, with costs equal to a conventional vehicle, to give more space to, for example, alternative fuel supplies which have not been adopted owing to their costs, such as hydrogen which is very suitable for the abovedescribed device.

The device also offers possible acoustics advantages compared with a conventional engine.

Variations may also be made to the abovedescribed device by, for example, providing one internal combustion engine, (figs. 4 and 5) mounted above or below the magnetorotor 5, instead of two, and, instead of a simple magnetorotor, a double one 3, 3' (fig. 4) or more generally a multiple one may be used, carrying magnets with the poles oriented as shown in fig. 4, in order to achieve a sort of "double effect", with higher power, or, moreover, the number of coaxial rotating cylinders would be greater than two, and more than one system of magnets could be operated by pistons 5.



In dimensioning the magnetorotors it will have to be taken into account that, for two integral coaxial rotors, with peripheral speed equal to wr_1 and wr_2 , respectively, the distance between two adjacent magnets shall respect the relation:

5 $p_1 : p_2 = r_1 : r_2$

wherein: p_1 = distance of magnets on rotor 1.

p_2 = distance of magnets on rotor 2.

10 r_1 = rotor 1 radius.

r_2 = rotor 2 radius.

However, it is not strictly necessary, if not considering the power at stake, that members 1ⁱ and 2ⁱ are both magnetized: one of them, preferably 2ⁱ, may be simply made from a
15 ferromagnetic metal; therewith further reducing the propeller's cost.

As already mentioned, the magnets can be suitably oriented, with or without flux baffles
13 mounted on them (see fig. 6), and can be variously spaced, or quite contiguous.

20 A further advantage to point out is the very unlikely probability of failures due to breakages: there are few parts that come in contact and, moreover, an incorrect timing will only reduce the engine's efficiency, even down to zero, but without further risks.



It is interesting to consider the energy "blocks" balance involved in the working of the apparatuses according to the invention.

By naming:

E_s the total energy to be provided to the system;

E energy generated by one combustion;

E_c energy for the compression inside the cylinder;

L_M total energy needed for separating magnets 2^i from magnets 1^i ;

L_{M2} total energy needed for opposing magnets 2^i against the repulsive magnets fixed on the second magnetorotor 3;

L_K compression work effected by mechanical energy restituting system 8;

L_y energy supplied along axis y, and therefore to pistons 5, by magnets 2^i during their approaching return-stroke toward magnets 1^i ;

L_x energy drawn along axis x, i.e. according to the magnetorotor's rotation;

and considering that, because of previously mentioned energy reasons, the total potential energy lost by magnets 1^i and 2^i , L_M is equal to $L_x + L_y$, it is possible to write:

$$E_s = L_M + L_K$$

$$E_c = L_K + L_y$$

and, subtracting member by member:

$$E = E_s - E_c = L_M - L_y$$

i.e. substituting

$$E = E_s - E_c = L_x$$

In other words considering the compression work as recovered energy, it is obtained that, excluding losses due to friction (very low) for example of members 11 on bushings 21 (fig. 4), the consumed energy E is exactly equal to the energy drawn on magnetorotor (excluding the



thermodynamic efficiency).

In the case of double or multiple magnetorotors, if the magnets mounted on second rotor 3' exist, it will be necessary to supply the energy L_{M2} or opposing them against magnets 2ⁱ, thus increasing the power, but reducing efficiency and lifetime of the magnets. The opportunity of using repelling magnets, therefore, has to be carefully examined case by case.

With multiple magnetorotors, but only with attractive magnets, the energetic arguments however remain valid, and higher powers and compressions will be achieved.

As both the method according to the invention and the propeller adapted to realize it are completely new, it is obvious that a wide range of modifications and improvements are possible, so as to achieve the best results for the different appliances; the embodiments shown in the accompanying drawings and mentioned in the description concern therefore only preferred examples, and are not binding or not limiting with respect to the subject matter of claim 1 and of the dependent claims thereto.

It is easy to understand that the adjustments of the device, in the case, for example, of constant power and rotation speed, such as when it is coupled to a generator, are very simple.

In that specific case, though, for discontinuous functioning, it will be necessary to start the device by means of an automatic starting device of known type, which will have, to let magnetorotor 3 rotate by only a small initial rotation angle, without having to effect any compression cycle.

The internal combustion engine most easily adaptable to be coupled to one or many magnetorotors will now receive a more detailed description.

30

With reference to figs 10 and 13, the fuel is introduced into the combustion chambers 9' of a selected number of cylinders 9 by means of preferably direct electronic injection, according to the torque or the power needed at each moment.



The timing of such injections, its regulation and the ignition time, when not in presence of a Diesel self-igniting cycle, are all controlled, as said, by an electronic control system of known type, such as a control-box which is programmed in such a way so as to continuously measure various parameters such as rotation speed of magnetorotor 3 (as
5 well as of shaft 7 fixed thereto), its angular acceleration and the requirements of a driver, for example, speeding up or slowing down, which is effected by moving an accelerator pedal, the brake pedal or other driving members.

Such a control-box 42 has been schematically represented only in figure 17.

10

In order to perform its functions it can be based, for example, on the measurements of the relative positions occupied by reference members located on magnetorotor 3, or on shaft 7, and on a non-rotating part.

15 The energy derived from fuel combustion, together with the compression energy of the work effected by the magnetic field and by the kinetic energy of pulsor 5 as well as of the members integral thereto due to the action of restituting system 8, cause separated magnets 1^i and 2^i , to follow one of the relative motion trajectories shown in figure 16, having a required inclination depending on the ratio between the speed of pulsor 5 along
20 its axis and the peripheral speed of magnets 1^i of the magnetorotor, and also depending on the inclination of the axis of the pulsors with respect to the surface of magnetorotor 3.

The work to be effected for quickly separating said magnets is equal to



the total potential energy of the magnetic field, but a part of it will be restituted by the magnetic field in the form of compression work in the next cycle.

5 That means that, if the fuel combustion supplies pulsor 5 with an amount of energy in predetermined measure higher than the difference between said total potential energy and said restituted compression work, the same pulsor will gain a certain amount of residual kinetic energy, effecting a longer compression stroke in the following cycle. On the
10 contrary, supplying said pulsor 5 with an amount of energy exactly equal to the above difference, the same pulsor will move with the same velocities as in the previous cycle, velocities mostly caused by the expansion of the compressed gas (at different compression ratios depending on the rotation speed of magnetorotor 3).

15 In other words, the combustion energy adds itself to the gas expansion's energy, in order to supply the system with the energy which is drawn at each cycle by the magnetorotor 3.

20 In fact, knowing the mass of all the members integral to the pulsor during its motion, (i.e.) magnets 2^i fixed thereon plus members 14 supporting and connecting them to pulsor 5), and the mass of same pulsor, it is easy to determine how much caloric energy is needed in order that the pulsor, after the combustion, and after having separated magnets 1^i and 2^i , keeps a required velocity v_p along the direction of
25 its axis. Referring to figure 16: given the rotation speed of magnetorotor 3 as well as its peripheral velocity ωr , the amount of calorific energy (i.e. the fuel amount) is regulated so as to generate the required ratio between said peripheral speed ωr and v_p , in such a way as to originate relative motion trajectories, during separating and
30 approaching strokes of magnets 2^i with respect to magnets 1^i , with the most suitable inclination for properly dividing in a required way the magnetic field energy between drawn mechanical work and compression work in the cylinders and/or for obtaining mechanical work according to a rotation sense or to the opposite one.

35 In the present description both members 1^i and 2^i are for conciseness

named "magnets", but in reality, when the required power is not high, members 2^i are preferably simple ferromagnetic members, eventually made from thin insulated metal sheets with the axis substantially parallel to the trajectory along which member 2^i run while the linked flux variation reaches its maximum value.

That allows smaller variations of the magnetic quantities B and H linked to magnets 1^i during their relative movement with respect to members 2^i , assuring a longer efficiency of magnets 1^i even without a cooling action. As a result the magnetorotor's cost, is considerably reduced.

The eventual small loss of permanent induction flux of the magnets which should occur after a certain period of use can however be recovered, at the end of said period, letting a direct current flow through coils 43 (figure 14), permanently fixed around magnets 1^i and, for example, immersed within a resinous supporting layer 44; such coils are normally open while the motor works, in order not to create inducted magnetic fields, which are disadvantageous for the dynamic and energetic balance of the engine.

The cursor supporting magnet 2^i , moving integrally to pulsor 5 even only by effect of mechanical contact, during the outward stroke, meets the restituting system 8 at point B and then, because of losing its kinetic energy at point C, runs back in the opposite direction and (not taking into account energy losses due to friction, which are however very small) with the same kinetic energy, i.e., the masses being constant, with the same (as absolute value) velocity $-V_p$, in the direction represented in figure 16.

It will thus run an almost rectilinear stroke DE, being contemporarily attracted with increasing intensity by the following magnet 1^i , and the pulsor integral to the said magnet will begin the compression for the next cycle.

Due to the simultaneous actions of the residual kinetic energy, of the magnetic field of 1^i and of the resistance to the compression effected by the gas contained inside the cylinder, it will follow the trajectory

portion EF, while the required amount of fuel is injected, suitably timed and regulated, into combustion chamber 9' of cylinder 9, fuel which will be, again with suitable timing ignited.

- 5 Such ignition, in addition to the effect of the expansion of the compressed gas, will cause a quick pressure-increase inside the cylinder when the pulsor finds itself at point A, following which the pulsor will be pushed back, as already said, at a predetermined velocity v_p .
- 10 For different rotation speeds of the cylinder, it will be possible to choose suitable values of v_p so as to obtain the most advantages trajectories under the aspect of mechanical and energetic efficiency.

The portions of trajectory due to the suction and scavenge-phase have not been shown
15 in detail, obviously they are portions with a constant value of v_p .

In the case of high powers and rotation speeds, the amount of kinetic energy to be used is big, and consequently high compression ratios around 40 : 1 and over, are reached, in order not to excessively increase the area of pulsors 5, (which can be however more
20 than one for each magnet, stacked upon one another), it is advisable to use diesel fuel or similar suitable essences as fuel.

In case of lower compression rates any kind of fuel can be used, provided that electrodes
25 33 (figure 12) are inserted, for the fuel timed ignition.

The theoretical explanation of the results of low specific fuel consumption offered by an engine operating according to the invention can be deduced from the formula of the ideal thermodynamic, efficiency rate η_{id} of the Diesel cycle taken as reference-cycle, wherein:

30

$$(K) \eta_{id} = 1 - \frac{1}{\rho^{\gamma-1}} \frac{\tau^{\gamma} - 1}{(\tau - 1)^{\gamma}}$$

(In reality with the present engine any kind of cycle can theoretically be obtained for the



same kind of fuel.)

wherein:

- γ' the ratio between final and initial temperatures of the combustion during the phase at constant pressure;
- x is the ratio between the specific heats which can orientatively be assumed as equal to 1.40;
- ρ is the compression ratio, which varies in the concerned engine.

10 As already explained in the description, ρ varies depending on the supplied power, i.e. on the return-stroke length of the pulsors, and again according to such stroke the amount of fuel to be burnt in a cycle is different, said amount being proportional to the total work to make in order to separate magnets 2ⁱ from magnets 1ⁱ.

15 The amount of air in the cylinder is substantially constant. This causes the temperature increase in a cycle due to the combustion to vary according to the drawn power, and similarly the behaviour of the temperature-increase due to the compression of the gases inside the cylinder.

20 Assuming that the air is sucked in at a temperature of 27°C, in a theoretical case, for example, at the maximum power, the gas temperature at the end of the compression ($\rho = 9$) is about 433°C, the Δt (temperature increase) due the combustion is (only) 120°C and the final temperature is 553°C; accordingly:

25 at maximum power : $\rho = 9$; $\gamma' = 1.17$; $\gamma'^x = 1.24$

Substituting said measures in (K), the efficiency ratios are as follows:

as maximum power $\eta_{id} = 0.58$

30

As it can be clearly seen, with a compression rate $\rho = 9$ it is possible to achieve thermodynamic efficiencies higher than the maximum efficiency of a traditional Diesel engine at the best conditions, with the same ρ .



Furthermore considering that, with the relatively low cited temperatures, the external thermal losses are easily reduced and the dissociation of H_2O and CO_2 is extremely limited, if not quite zero, the thermal + thermodynamic efficiency of the engine concerned is easily comparable with the same efficiency of the traditional internal combustion engines.

It has to be further added that the mechanical + organic efficiency of the engine, from the cylinder up to the gear-box, in the related example can be assumed as ranging around $0,90 \div 0,92$, whilst the same efficiency for a traditional fixed-geometry engine with crank-shaft, normally is not too far from 0,60.

At this point of the explanations it is useful to describe an example of approximate planning of an engine according to the invention, working accordingly to the related method.

First of all the inclination of the pulsors with respect to the magnetorotor's magnets are prefixed. (For example 45°).

Due to this inclination, about 68 % of the total work L_M of magnetic fields gives mechanical work, the remaining about 32 % gives compression work L_C .

When separating the magnets, while they are running stroke AB of figure 16, an extra-amount of mechanical work ΔE is drawn, approximately equal to the 30 % of the total magnetic fields work. It is therefore possible, for the approximate planning, to consider the total mechanical power as substantially equal to the total fields work L_M per second.

Said work is expressed as follows:

$$L_M = \frac{1}{Z} F_{pn} \Delta l \cdot q^2 \cdot p \cdot n$$

(Z is a numeric coefficient which may be assumed as ≈ 7)

Wherein:

- F_{pn} is the total attraction force exerted by the magnets connected to a pulsor, approximately equal to the 80 % of the theoretical force between the magnets at zero-distance since in the reality, between the magnets even when as close as possible to each other, a space of few tenths of millimeter is always to be left;
- Δl is the maximum distance where the attraction force between the magnets is "sensible", assuming such force, for example, equal to $\frac{1}{200}$ of the above described maximum force;
- q is the number of magnets located on a magnetorotor's circumference;
- p is the number of said circumferences vertically laid one over another;
- n is the maximum rotation speed of magnetorotor, measured in revolutions per second.

Once fixed the mechanical power to draw, in order to dimension the motor cylinders, a stroke of the pulsors is prefixed, which causes the magnets to move away from one another substantially up to the above cited border distance of sensible attraction; for example:

$$\text{stroke} = C = 0,95 \cdot \Delta l \cdot 1,4$$

(coefficient 1,4 is due to the mentioned pulsors inclination and is $\approx \frac{1}{\sin \alpha}$)

Then, the force, which acts on the pulsors in order to separate the magnets with an acceleration sufficient to let them follow the trajectory shown in figure 16 is evaluated. Practically so as not to have braking forces, the move-away line must be at least perpendicular to the magnetorotor already at point x, and that is obtainable by means of a pulsor-velocity v_p approximately equal to 1,5 times the peripheral velocity of the magnetorotor after a very short time, which can for instance be assumed as equal to the time of a tangential relative movement of $\frac{l}{6} + \frac{l}{40}$ of their width l .

Such time t is for example:

$$t = \frac{J}{g} \frac{\rho}{\omega r};$$

the required force, not considering minor differences, is expressed as follows:

$$F = \frac{m V_p}{t}$$

wherein m is the mass of the pulsors plus the mass of everything integral thereto (pivots 11, cursors 14, magnets 2ⁱ etc.)

Given this force, the "outward" force $S \Delta p$, which the compressed gas, even without the help of the combustion, has to exert on the pulsor at the point A of maximum approach between the magnets can be deduced (S = pulsor area and Δp = pressure increase inside cylinder).

By effecting the calculations, it will be seen how the volumes of the cylinders are much bigger than the volumes corresponding to the stoichiometric ratio.

Owing to simple geometric reasons, such force

$$S \Delta p \text{ is: } S \Delta p = F + \frac{F_{pm}}{0.7} \cdot P$$

(resulting over-evaluated, since, because of the inclinations, F_p has not its full theoretical value).

After having evaluated the piston (pulsor) dimensions and the pressure inside the cylinder, it is easy to evaluate the adiabatic expansion's work L_e along stroke AB:

$$L_e = \frac{J}{k} (0.95.1.4. \Delta \ell) S \Delta p$$

(k is to be assumed dependent on $\int$, constant pressure / or volume specific heat c_p , c_v etc.)

When injecting the fuel, an amount thereof is injected, to produce, with the combustion inside the cylinder, an amount of energy equal to the

magnetic mechanical work for that single cycle, i.e. equal to the total magnetic energy per cycle minus the magnetic compression work L_c which pulsor-magnets will effect in the following cycle, plus the cited extra-amount of mechanical work ΔE_m .

Substantially, the energy supplied by the fuel, as said, is equal to the total magnetic work in the cycle (ignoring the efficiency ratios).

During the stroke AB the pulsors will be pushed by the gases expansion-work L_e , minus the magnetic compression work, and they will have, at point B, a residual kinetic energy E_v

$$E_v = L_e - L_c$$

Having evaluated this energy value, and given the mass m of pulsor, cursor etc., the final pulsor velocity in B is easily calculable, that is its velocity at the beginning of the compression of the resilient members of the mechanical energy restituting system.

Provided the kinematic questions concerning the relationship between pulsor velocity and corresponding magnetorotor velocity have been correctly evaluated the times of pulsor strokes AB and EF are easily calculated.

By subtracting these times from the total time spent by a magnet l^i for moving itself by one position, the time is obtained, within which compression plus expansion of said restituting system has to take place. Since the kinetic energy E_v absorbed and then restituted by the said system is known, the particulars of same system are easy to be determined; in the case of springs, for example, their maximum set, their rigidity and so on.

The above explanation can be adapted to each one of the different conditions of magnetorotor-speed, drawn power, compression etc., suitably acting on the timing of injection, ignition and combustion end of the fuel, advancing or retarding them so as to obtain the most proper trajectories, according to methods that are well known by people skilled in the field of internal combustion engines.

Once dimensioned the engine as above explained, β , τ' , τ^{ix} and η_{id} will

consequently reach the values already mentioned in this description, i.e. η_{id} , in particular, will range between 0,50 and 0,75 under the normal use conditions. The final efficiency rate will range between 0,46 and 0,52 with the engine power going from 30 to 1000 Hp.

From what has been said it is understandable that the engine subject of the invention, shows a specific fuel-consumption much lower than the traditional engines, with much lower pollution. The details of ignition and combustion of the fuel shall be determined, case by case, by technicians skilled in the engines field, taking into account the new situations of compression and temperatures, (which vary depending on the power used), in order to achieve the best work-cycle for each use-condition.

By combining the data supplied by the experience in the field of after-burners, as well as in the field of multifuel engines (Hesselman eng.), it will be possible to obtain the best solution for each single case.

A successful solution is suggested by fig. 12: the fuel is ejected by injectors 43 directly toward electrodes 33 (as in multifuel engines), which the fuel reaches after mixing with a prefixed mass of air.

Such air (conceptually corresponding to the primary air of the after-burning technology) will be formed from the air contained inside the pre-chamber 44 in addition to the air "sucked" by the fuel-jet through one or more than one air-ducts (46) because of Venturi effect.

The fuel, burning while crossing the electrodes area, transmits, as gradually as required, the effects of its pressure increase to the remaining gas (actually air) contained inside cylinder 9 during the first stage AX of pulsor 5 "move-away" stroke.

It should be noted that a.m. prechamber 44 is substantially "self-regulating": inside said prechamber at a certain compression ratio, a given mass of air is lodged, which combines itself with the amount of fuel needed for separating the magnets which are at the distance corresponding to said compression stage: by increasing the compression, at the same time the amount of fuel needed for separating

the magnets and the air mass increased, since they were closer than in the previous situation. The mass of air increases according to the compression curve, the amount of fuel increases according to the attraction-force curve depending on the distance between the magnets.

5
10
15
With the commonly used range of compression ratios $6 \leq \rho \leq 14$, the latter curve has a trend fairly similar to the adiabatic curve trend, and the relatively small differences of the various distance between the magnets can be corrected by regulating the strength of the compound generated in prechamber 44, modifying (very slightly) the amount of fuel, or the number of air-ducts (46), or the injection-pressure, or the prechamber volume, or all these factors together. Many pairs of electrodes can be installed along the longitudinal axis of the prechamber, so as to make it possible to start the ignition when the fuel is mixed with the required amount of air. (This case is not represented in the drawings).

20
In the case of very high power, i.e. of relatively high rotation speeds of the magnetorotor, with consequently high amounts of kinetic energy to be exploited during the return-stroke of pulsors 5, a part of such energy can be transformed into further air-compression work, that can be used to effect air expansion inside one or many stages of a turbine splined to the drive shaft 7.

25
Such a solution, which is especially suitable for naval and aeronautical appliances, has not been represented in the drawings, as it is easily imaginable by a person skilled in the engines-field.

As the engine is a two-stroke engine, it is necessary to scavenge the exhaust gas, sending it to the discharge duct 46 while pulsor 5 moves away from combustion-chamber 9'. That is effectable by means of a _____

substantially transverse pressurized air-jet, as shown in figure 10. Such a jet can be formed in various ways, with or without a pressurized air reservoir 32 acting as plenum chamber, by means of a compressor, with rotating members which is connected to the drive-shaft, or operated by electrical energy supplied for example by the batteries of the vehicle in which the engine is installed.

There is also the possibility (figure 10) to effect the compression by means of a plurality of pistons 26, preferably parallel to the engine-cylinders 9, of which one or more are connected by a coupling 45 to a pulsor 5, integral in motion to said pistons 26.

Each one of these pistons 26, after sucking air through the port 27, compresses it during the return-stroke up to the setting-pressure of a valve 28, through which the gas, at a prefixed pressure, is let into the plenum chamber 32 and subsequently passes, through the non-return valve 25 and duct 29, to the related cylinder 9.

The latter valve 25 is not essential for the cycle inside cylinder 9. Nevertheless said valve can sometimes be useful for avoiding an inadequate scavenge-air consumption by closing it in case, e.g., the total outward stroke of the pulsor is considerably higher than the expansion-stroke. Such a case will be described later. The shape of the section, its area and the useful stroke of such pistons 26 may be varied accordingly to the required pressurized-air flow-rate. The aforementioned compression can be effected during the return-stroke of pulsor 2, as represented in figure 10, or during their outward stroke (case not represented in the drawings).

Said system is especially suitable for the embodiment preferred by the inventor for not too high powers, wherein there are as many cylinders as magnets fixed along an outer circumference of magnetorotor 3.

As the pistons can be replaced with simple, preferably hollow shafts carrying pressure-seal rings 31, the cost of the parts is so low, that the use of the said volumetric compressing pistons is advantageous,

provided that their use would not cause unacceptable variations of the trajectory of magnets 2ⁱ.

If the above is correct an alternative independent air-compressing system may be used, both electric or eventually mechanically connected to drive-shaft 7 or to a secondary shaft derived therefrom.

The aspect of the engine is shown in fig. 13.

Given the high reaction-torque transmitted to the supporting frame, (the maximum rotation speed for usual appliances, is not higher than 6-10 revolutions per second), it is useful to split the required power in two by means of two counter-rotating engines which are mechanically in parallel or, by means of a known rotation reversing device, 35 fig. 15, in series.

In order to reduce the strains on members 14 (cursors) which support magnets 2ⁱ, and thus their mass and the related inertial force, the inventor foresees to insert each engine between two half magnetorotors (fig. 14). Such a solution also helps bushings 21 fig. 4 through which the supporting shafts 14 of the cursor run, especially in the cases of single magnetorotor, as shown in the mentioned fig. 14.

For cooling down, in the cases of higher powers, it is possible to leave space between the two casings containing two adjacent cylinders. By doing so, the equivalent exchange-area results multiplied by more than three times.

Naturally, cooling fins mounted on said cylinder-casings will further improve the heat exchange. In other cases, suitably oriented air streams may be used, and they may be generated by the vehicle motion or by cooling fans. In the case of very high power, if the air-cooling system were inadequate, it would be easy to cool the engine down by means of an heat transferring fluid circulating inside annular or otherwise shaped jackets to be mounted around the cylinder-casings. Such solution has not been represented in the drawings.

In most of cases, space problems are not met, since the magnetorotrs carry magnets 1ⁱ interspaced by at least a 50 ÷ 70 % of their width, in order to avoid interferences among the magnetic fields. All around the

5 engine 6 there is a plurality of free spaces between two adjacent
cursors 14 supporting a certain number of overlaid magnets. In case that
magnets 1¹, by the effect of flux-baffles fixed thereto, may be
contiguous, it will be sufficient to lose a certain percentage of power,
eliminating opposite pairs of cursors 14. Given the relatively low
10 temperatures, in the engine of the invention the lubricating system by
means of an heat transferring fluid is normally not needed. Each pulsor,
in fact, by the effect of the transversal scavenging air-jet, even if at
a pressure of 3 Kg/cm², exerts a pressure against the cylinder wall
corresponding approximately to 0,8 ÷ 1,5 Kg/cm², with a maximum piston
15 velocity of about 12 m/sec. A correct choice of materials and of
surface- treatments, as well as the eventual use of solid lubricants
such as molybdenite, are therefore adequate specially when using diesel
oil or similar essences as fuel (notoriously self-lubricating).

20 Pulsor 5, and consequently cylinders 1, never support any pressure
besides that mentioned above, and the limited pressure given by the seal
rings, not supporting other different kinds of forces having components
not parallel to the cylinders axes.

25 The present description is intended to give a wide enough explanation to
let a skilled people build the engine according to the invention, by
exploiting their specific experience in order to choose the best form
and location of the various parts and of the various ducts, the
materials to be used and so on.

30 One detail which the inventor suggests concerns the form of duct 29 of
the scavenging air-jet: it will be useful to shape it as orientatively
shown in fig. 10A, in order to perform an efficient scavenge in the
direction of the arrows also with a not high pressure and to be able to
eventually exploit part of the same pressure (the part which, because of
the tortuosness of the way does not transform itself into kinetic
energy) as first stage of the compression inside the cylinder, or for
creating a turbulence inside the cylinder.

35 As far as starting the engine is concerned, as already anticipated, it

is useful to foresee to let the magnetorotor rotate for example by means of a manual operation through a device of known type (for instance, inertial), connected to a floor-type gearshift.

5 Magnets 2ⁱ, which are inactive at this stage, oscillate staying at an intermediate distance, between the field-limit and magnets 1, which does not generate undesirable Foucault effects, at the intersection point between the pressures curve and the attraction forces curve of the magnetic field.

10 Once the minimum rotation speed is reached, the first injection/ignition will take place, and the engine, from then on, will run itself by means of the control box 42. It is however obvious that, in the case of high magnetic-field intensity, a small electric device of known type may be
15 connected to the drive-shaft, making it rotate anyway by a limited rotation angle, without having to effect compression cycles inside the cylinders.

20 From the above, it is understandable that the engine according to the invention, either when the vehicle is not going, or even just when the accelerator-pedal is totally released, is inactive and doesn't burn fuel (or emit exhaust gases).

25 It is of interest to note that, by quickly releasing the accelerator pedal, and deactivating (intending to slow-down the vehicle), the pulsors, they, devoid of the kinetic energy supplied by fuel, will follow, with decreasing stroke-length, trajectories no longer adapt to generate a working torque, but on the contrary, generate a braking torque, as said trajectories will cross the magnets attraction field in
30 such a way as to slow-down the magnetorotor motion as well as the thereto connected drive-shaft 7.

35 By suitably programming the electronic control device, it is also possible to deliberately create, by means of the fuel injection, such trajectories, for example as the driver, after having quickly released the accelerator pedal, roughly presses (giving it a reference-acceleration basing on which the control device is programmed)

the brake pedal. By doing this, the vehicle is slowed down (braking-motor effect), in co-operation with the existing braking-system.

5 Thanks to the possibility to activate a selectable number of cylinders, with again variable power per cylinder without meeting the problems caused by the crankshaft, not present in a motor according to the invention, a gear box is in certain cases not strictly needed: also the reverse motion, for example, will be in some cases achievable by means
10 of suitable trajectories (AKZ fig. 16).

In the remaining cases, a simple insertable reverse gear, or a two-three-gear gear-box will be adequate. The fuel consumption of the referenced engine, thanks to the best exploitation of the various kinds
15 of energy used, is as said, very low: the theoretical fuel-consumption with a power of 82 HP is approximately one liter of fuel per 20 Km running at the maximum speed, and decreases then approximately with the speed cube, as it has been demonstrated in the present description.

20 The engine works, as previously stated, with a variable compression, increasing together with the increasing power, and with the need, as also said, to increase the fuel quantity. The resulting air volume inside the cylinders considerably exceeds the stoichiometrically required volume: consequently the substantial absence of CO, HC and of
25 many nitrogen compounds within the gas is achieved, and a good combustion efficiency is also achieved at low speeds, with low compression ratios.

30 That, together with the very low consumption at low speeds and the inactivity when the vehicle is not in motion, makes it advantageous to use the engine for citytravelling as it produces a low pollution rate.

The economical and enviromental results achieved by this motor are immediately obvious: they add to the possibility of obtaining good
35 acceleration at any intermediate speed without torque-amplification systems for heavy vehicles.

Especially adapted for the use on any kind of transportation-means: cars, aircrafts, ships, it is quite suitable for being used on a helicopter.

5 The drive shaft rotation speed (6 : 10 r/sec) is in fact, very close to the commonly adopted rotation speed of the propeller-shaft. The heat emitted by motor 6 by radiation can easily be kept from reaching the magnets 1ⁱ of the magnetorotor 3 by applying, an insulating layer covered by a thin sheet of reflecting material to the inside of magnetorotor 3. The low level of heat eventually produced by the magnets because of parasitic currents or because of other energy losses is automatically removed by air by the effect of the pulsating motion of cursors 14 combined with the rotative motion of magnetorotor 3.

15 An interesting possibility of varying the trajectories of the motion of magnets 2ⁱ fixed on cursors 14 in a further suitable way deserves an explanation. It can be achieved by varying the distance between restituting systems 8 and cursors 14 for a constant magnetorotor 3 rotation speed. By doing so, a more advantageous torque/speed curve is obtained. Considering fig. 17, the device shows, in one of the preferred embodiments, a stiff member 40 fixed to the radially outer ends of elements 8 elastic to the compression stress spring (in the case shown) which have to take up the maximum kinetic energy of a pulsor 5 or of a group of mechanically connected pulsors by means of a prefixed maximum set.

20 A flat plate 37, parallel to the slidable facing member 40, is interposed between same member 40 and a fixed structure 20, said plate carrying at least one wedge-shaped projecting part 37', thickness of which decreases along its longitudinal axis, at positions corresponding to each elastic element 8 or group of elastic elements.

30 By allowing said plate 37 to slide longitudinally with respect to member 40, the wedge-shaped projecting parts 37' fit between member 40 and structure 20, modifying the distance between them from zero up to the maximum thickness of wedge-shaped projecting part. Such a projecting

part 37', when not totally inserted between member 40 and structure 20, projects sideways through holes 40' formed on same member. Many methods can be used to allow said slidable plate 37 slide, for example, fixing one end 37" thereof to the keeper of an electromagnet 38, whose induction current is controlled by the engine's control box, which determines its stroke according to the angular speed or acceleration, to the instructions given by the driver, or to the length of the compression stroke runnen in the last cycle, or to many of these factors combined with each other.

It is possible to modify the device by connecting springs 8 to related cursors 14 instead of to the stiff member 40.

Said modification doesn't need any further explanation, as it would appear obvious to people skilled in the art.

The advantages offered by the invention are evident. Referring to fig. 18, the best trajectory normally achievable with a magnetorotor (ABC), or with the use of above described device (DEF) for a given rotation speed are shown: the velocity v_p of pulsor 1, in the represented case, is multiplied by more than three, and accordingly is multiplied by 3 the compression work performed by pulsor 1 consequently the approach-stroke of the magnets increases by approximately $\sqrt{3} = 1,75$ times, and that causes a power- and torque-increase, for the given rotation speed ω^2 of the magnetorotor, of about 3 times, as previously mentioned.

(The length of segment HK is equal to the thickness of wedge-shaped projection 37'). By suitably dimensioning every part, it is possible to obtain the maximum torque for any rotation speed used.

A further method for moving slidable plate 37 may be by connecting it to a pneumatic, oil-operated or similarly operated piston, "driven" by the control-box, or to insert a sealed expandable chamber between member 40 and fixed structure 20, regulating, again by means of the control-box, its thickness, or to use other methods not shown in the drawings.

As already mentioned, in the (frequent) cases wherein the above described device is used, it may be useful to have the ability to shut,

the scavenge-air inlet valve (25) by way of one of the several known systems, when pulsor (5) has reached a prefixed position during its outward stroke.

5 So that inadequate amounts of compressed scavenge-air are not wasted, worsening the global efficiency rate of the engine.

From what has been described up this point, it can be deduced that, in a magnetorotors-engine comprising the latter described device, it is possible to perform the following functions:

10 - at constant magnetorotor rotation speed, to vary the torque, hence the power on the drive-shaft, by modifying the cursors stroke-length and the fuel amount, or

15 - achieving a constant torque for different rotation speeds of the magnetorotor, i.e. of the drive shaft, by keeping the fuel-amount per cycle substantially constant and modifying the cursors stroke-length.

It is clearly possible, by means of a suitably programmed control-box, to effect a wide interpolation, therefore obtaining, for each use
20 condition of the engine, the required torque and power.

25

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. Method for moving a first member bearing a first group of permanent magnets
5 of the same polarity along a circular trajectory by moving, by a reciprocating motion,
a second member, or a plurality of second members, bearing a second group of
permanent magnets and having no mechanical connection to the first member, along a
rectilinear trajectory which is traverse to said circular trajectory, said first member being
10 a magnetorotor, connected to a drive shaft and bearing the permanent magnets fixed
around its outer circumference, said first member moving according to a rotative motion
around an axis which is perpendicular to the plane on which the permanent magnets of
said second member are radially distributed, and passes through the geometrical center
of said circumference, said second member, or plurality of second members, having the
15 permanent magnets distributed around said geometrical center, facing the first group of
permanent magnets and being mechanically connected to piston(s) of an internal
combustion engine, and energy restituting means being provided that are compressed by
move-away motion of the pistons consequent to the gas combustion and expansion,
reciprocating the motion during the return and compression phase of the engine, the
method comprising effecting movement of the second group of magnets of the second
20 member(s), by action of the energy restitution means on the piston(s), to a proximity
relative to the first group of permanent magnets whereby movement of the first group
of permanent magnets toward the second group is effected by virtue of magnetic
attraction therebetween, and subsequently moving the second group of magnets away
from such proximity and magnetic attraction, along the same rectilinear trajectory, just
25 before the poles mesh, as an effect of the move-away motion of the piston(s) consequent
to the gas combustion and expansion.

2. Method according to claim 1 wherein the magnets of either the first or second
member are ferromagnetic parts.

3. Method according to claim 1 or 2 wherein the pistons are driven by ball bushings.



4. Apparatus which comprises:

(a) a first member which is a magnetorotor, bearing a first group of permanent magnets of the same polarity that are fixed around its outer circumference,

5

(b) a second member, or a plurality of second members, having no mechanical connection to the first member, bearing a second group of magnets, facing the first group of permanent magnets and moving, by a reciprocating motion, along a rectilinear trajectory which is traverse to the circular trajectory of the first member, the first member rotating about an axis which is perpendicular to the plane on which the permanent magnets of the second member, or a plurality of second members, are radially distributed and passes through the geometrical center of said circumference, said first member being connected to a drive shaft;

10

15 (c) an internal combustion engine with a combustion chamber;

(d) energy restituting means that are compressed during the move-away motion of piston(s) of the engine, after the gas combustion and expansion and reciprocate the motion during the return and compression phase of the engine cycle;

20

wherein said first group of permanent magnets faces said second group of permanent magnets with opposing polarity, the second member moving the first member as a result of the magnetic attraction between said two groups of permanent magnets, and said internal combustion engine has its combustion chamber directed toward the said geometrical center, said second group of magnets of the second member(s) moving the first member by entering the field of magnetic interaction with said first group of permanent magnets as an effect of the action of the energy restituting means on piston(s) that are coupled thereto and subsequently being moved away from the first group of magnets, along the same rectilinear trajectory, just before poles of the groups of magnets mesh, as an effect of the move-away motion of the piston(s) consequent to the gas combustion and expansion.

25

30



5. Apparatus according to claim 4 wherein the magnets of either the first or second

member are ferromagnetic parts .

6. Apparatus as claimed in claim 4 or 5, wherein the internal combustion engine is
5 a two-stroke star-engine, having pistons, which may also be called pulsors, housed inside
cylinders with their heads facing the center of the engine, whereby combustion chambers
of the cylinders are located between said heads and the geometrical center, the pistons
being provided with carrying members for coupling the pistons to the second member(s)
named cursors, on which the second group of magnets are fixed.

10

7. Apparatus according to claim 6, wherein of each cylinder includes a lid provided
with one or more air-ducts and with a pre-chamber in which the ignition electrodes and
the fuel injector are installed, each cylinder being shaped and dimensioned in such a
way, that a prefixed amount of fuel, injected at a predetermined pressure by said
15 injector, reaches said electrodes after having mixed itself with the stoichiometric amount
of air drawn through the air-ducts and inside the pre-chamber.

8. Apparatus as claimed in claim 7, characterized in that exhausted compound
scavenge is effected in each cylinder, after an explosion, by an air-jet directed
20 substantially transverse to the axis of same cylinder, which comes from a device capable
of compressing air and sending compressed air, into each of said cylinders.

9. Apparatus as claimed in claim 8, characterized in that the device capable of
compressing air is a compressor, mechanically connected to the drive shaft or to a
25 derivation thereof.

10. Apparatus as claimed in claim 8, wherein said device capable of compressing air
is a compressor operated by an electrical motor.

30 11. Apparatus as claimed in claim 8, wherein the device capable of compressing air
is a volumetric compressor, formed by a plurality of pistons, operating in accordance
with the rectilinear reciprocating motion of engine pulsors, to which they are
mechanically connected.



mechanically connected.

12. Apparatus as claimed in claim 8, wherein the compression of air is effected by both a compressor, which is either mechanically connected to the drive shaft or
5 electrically operated, and by a plurality of pistons, integrating their action according to the required compressed air flow-rate and pressure.

13. Apparatus as claimed in any one of claims 8 to 12, characterized in that the exhausted compound scavenge-air is emitted by the compressor into a reservoir
10 (plenum chamber), and subsequently into the cylinders.

14. Apparatus as claimed in any one of claims 6 to 13, characterized in that fuel injection and ignition in each cylinder take place by effect of the action of an electronic control-system.

15
15. Apparatus as claimed in claim 14, characterized in that the timing of the fuel injection and ignition inside the explosion chamber are determined by said control system according to the mutual position occupied by reference-members located on magnetorotor and on a non-rotating part of the apparatus.

20
16. Apparatus as claimed in claim 15, wherein said control system effects said timing and the regulation of the amount of fuel emitted for a single explosion depending on the peripheral velocity, angular acceleration, of the magnetorotor or on the position occupied by one or more drive-operated drive-members, or on the compression-stroke
25 following the last explosion, or a combination thereof.

17. Apparatus as claimed in any one of the preceding claims 4 to 16, characterized by the axis of motion of the pistons being inclined with respect to the outer surface of the first group of permanent magnets in order that the relative-motion trajectories of the
30 second group of magnets with respect to the magnetorotor have prefixed inclinations, said second group of magnets being pushed by the pistons during their out-ward stroke from the first group of magnets, and toward the first group of magnets by the restituting means and by the magnetic field during the related approach-stroke.

means and by the magnetic field during the related approach-stroke.

18. Apparatus according to any one of preceding claims 4 to 17, wherein the restituting means, coupled to the engine pistons, consists of a plurality of elastic-to-
5 compression elements or group of elements, located circumferentially around the magnetorotor in correspondence of each piston or of each group of interconnected pistons, the longitudinal axis of each element being aligned with or parallel to the axis of the related piston or pistons, and each element having its radially outer end turned
10 toward a fixed structure, characterized in that all said groups of elastic elements are connected by a rigid member and in that a spacer member is interposed between the second member(s) and the fixed structure, said spacer member being able to modify the distance between the second member(s) and the fixed structure while the magnetorotor is operational.

15 19. Apparatus according to claim 18, wherein the spacer member interposed between said second member(s) and said fixed structure is a flat plate, parallelly facing said second member(s), the plate provided with at least a wedge-shaped projecting part, whose thickness increases along its longitudinal axis, located in correspondence of each said group of elastic elements, and in that said member carries a plurality of notches,
20 inside which said projecting parts can slide while effecting their stroke.

20. Apparatus as claimed in claim 19, wherein each one of said plates is connected to a device allowing them to longitudinally slide with respect to second member(s).

25 21. Apparatus as claimed in claim 20, wherein the device capable of allowing each one of said plates to slide is an electromagnet bucked by a counter-acting spring.

22. Apparatus as claimed in claim 20, characterized in that said device is a pneumatic or oil-operated cylinder.

30

23. Apparatus as claimed in either of claim 21 or 22, wherein a prefixed length sliding-stroke of said plates is generated by one of said devices, upon control of the control system coupled to the magnetorotor, according to the magnetorotor's angular

control system coupled to the magnetorotor, according to the magnetorotor's angular speed or acceleration, or to instructions given by a driver, or to the length of the compression-stroke of the pistons following the last explosion, or to more than one of
5 above combined with each other.

24. Apparatus as claimed in any one of claims 18 to 23, characterised in that said elastic elements are flexion or torsion springs having a rigidity coefficient such that, for the maximum set of a group of springs, the maximum kinetic energy of piston or pistons
10 related thereto is absorbed.

25. A method for moving a first member bearing a first group of permanent magnets of the same polarity along a circular trajectory by moving, by a reciprocating motion, a second member, or a plurality of second member, bearing a second group of permanent
15 magnets substantially as hereinbefore described with reference to the accompanying drawings.

26. An apparatus for moving a first member bearing a first group of permanent magnets of the same polarity along a circular trajectory by moving, by a reciprocating
20 motion, a second member, or a plurality of second member, bearing a second group of permanent magnets substantially as hereinbefore described with reference to the accompanying drawings.

DATED this 8th day of May, 1995

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By Its Patent Attorneys

DAVIES COLLISON CAVE



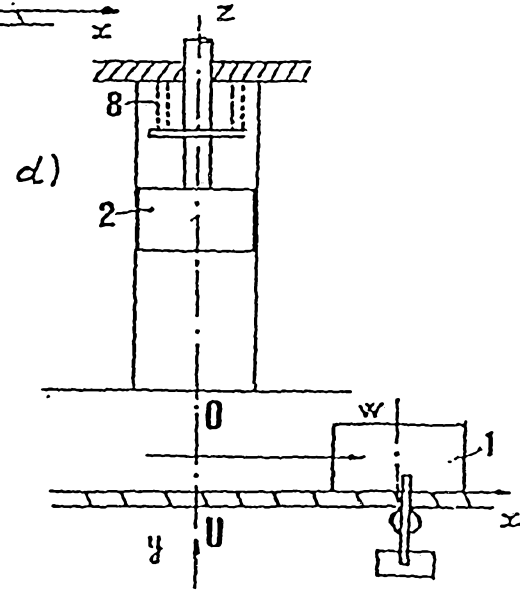
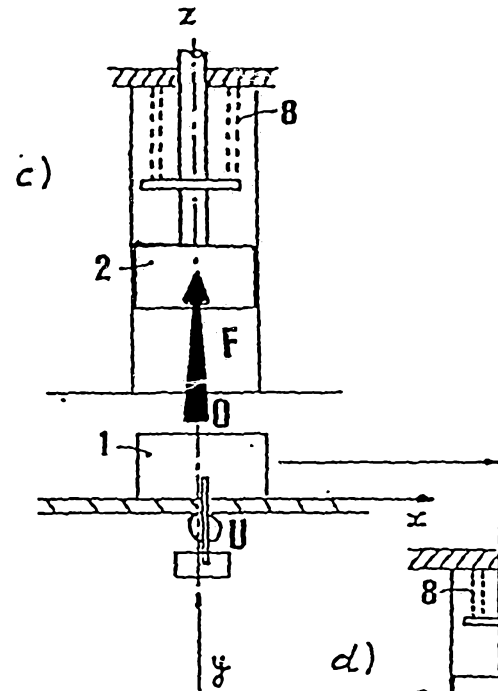
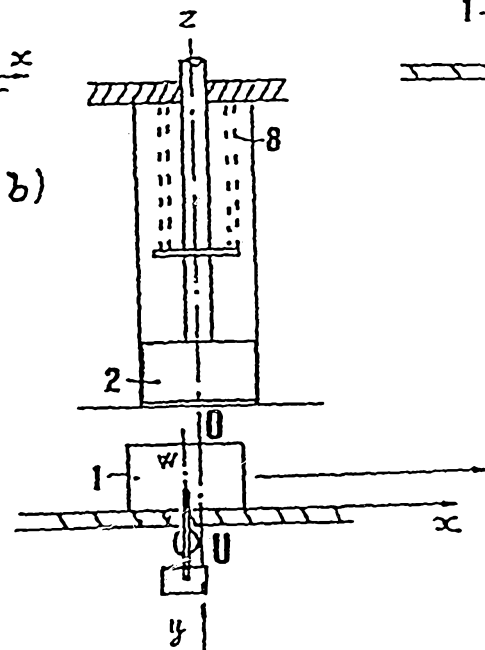
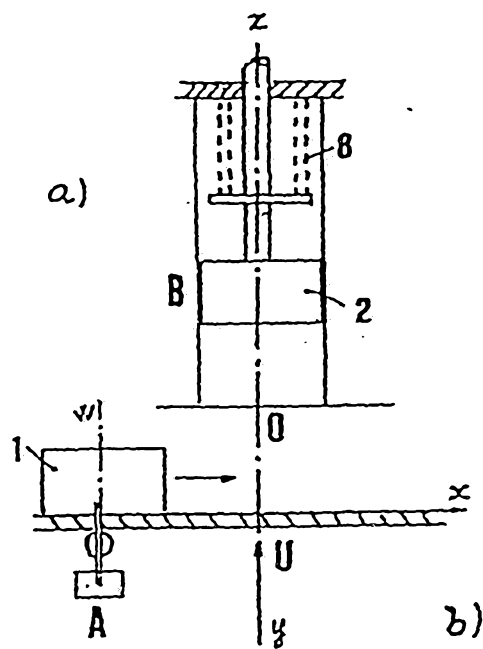


FIG. 1

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FIG. 4

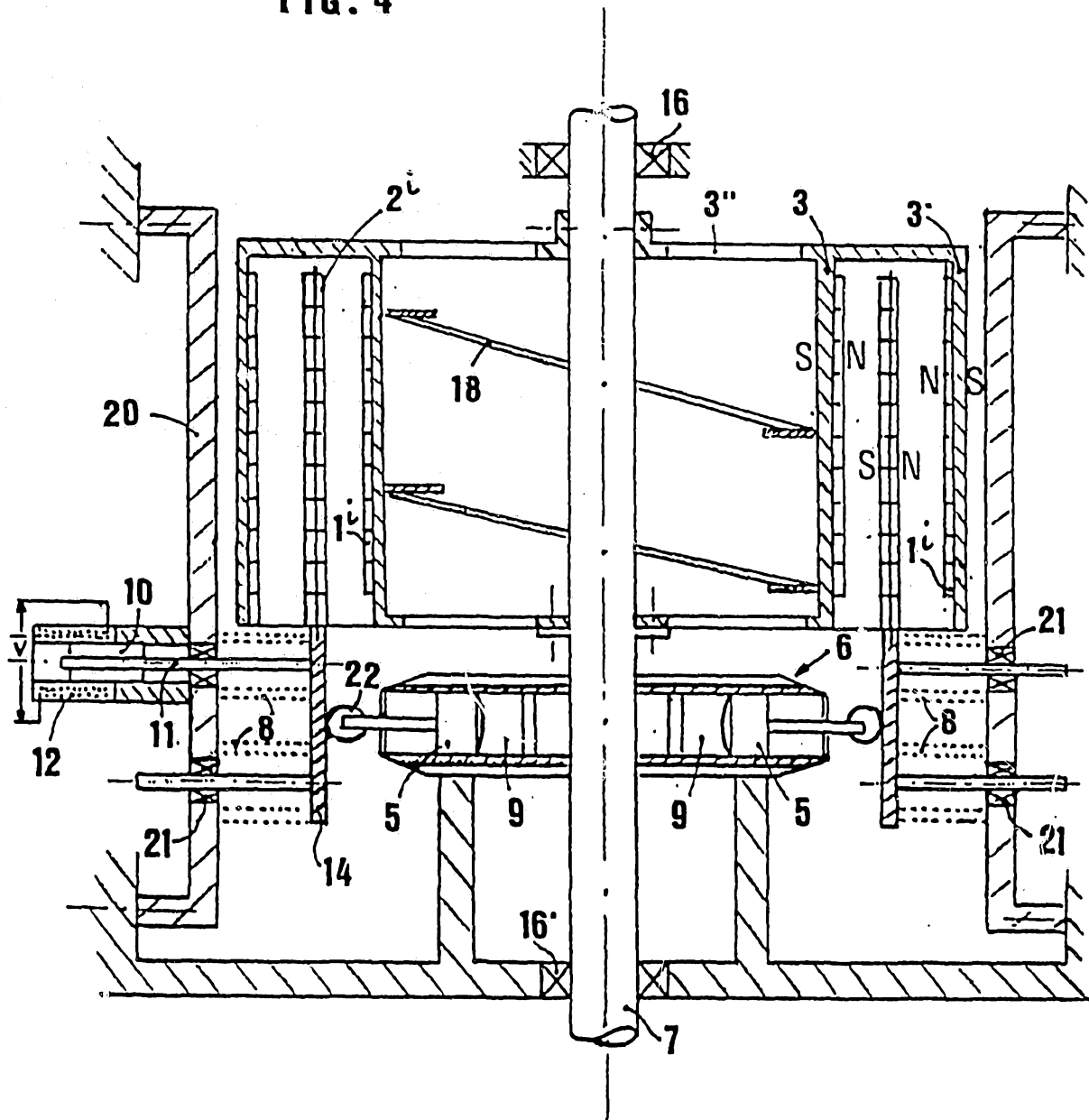
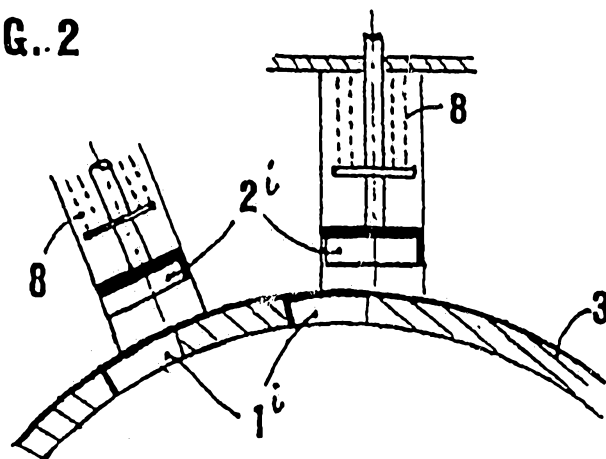


FIG. 2



SUBSTITUTE SHEET

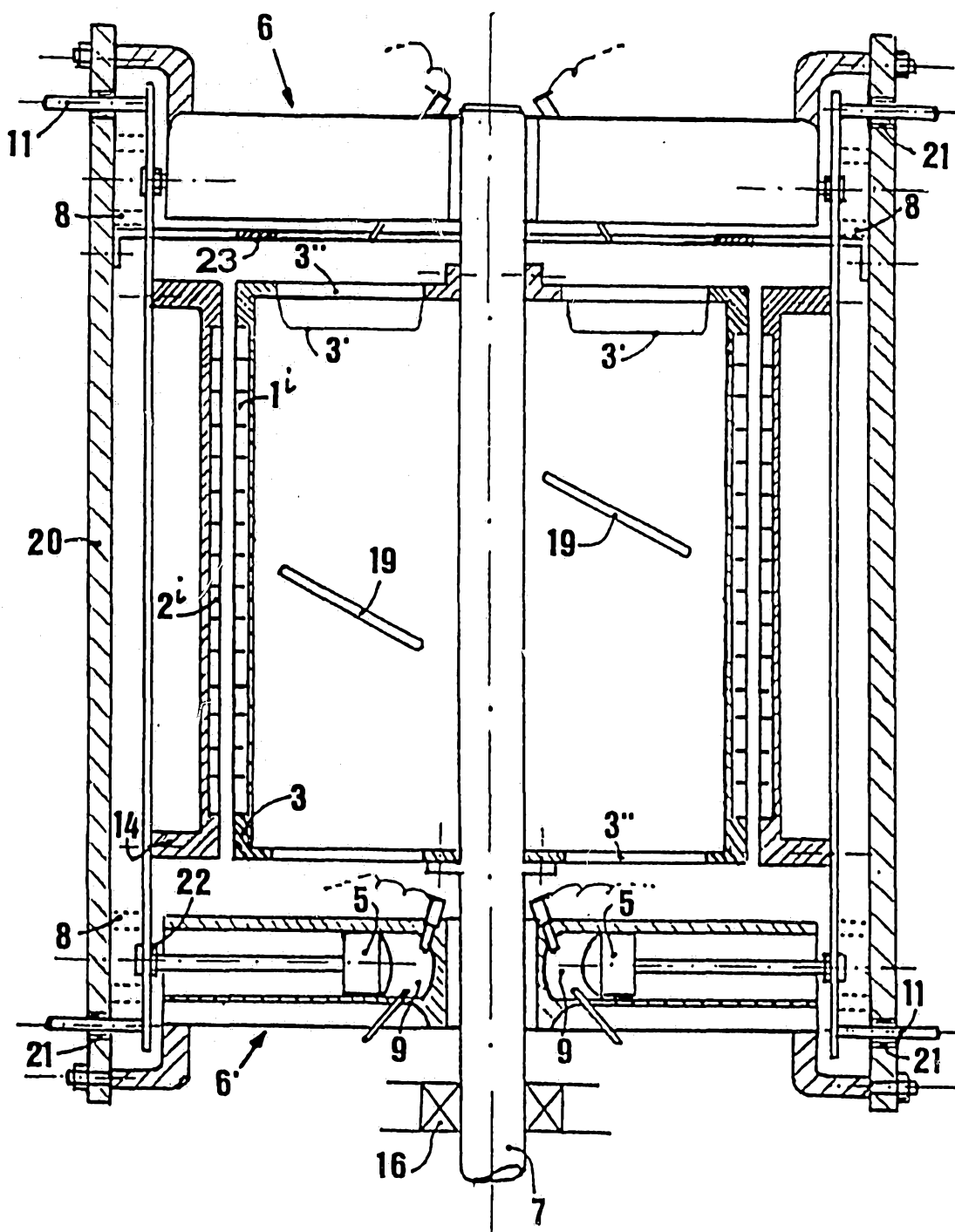


FIG. 3

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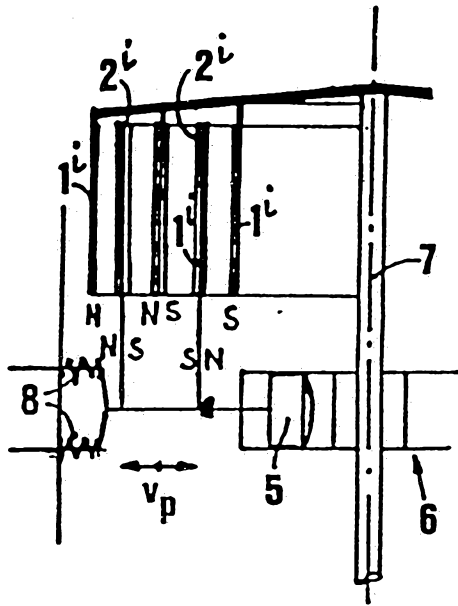


FIG. 5

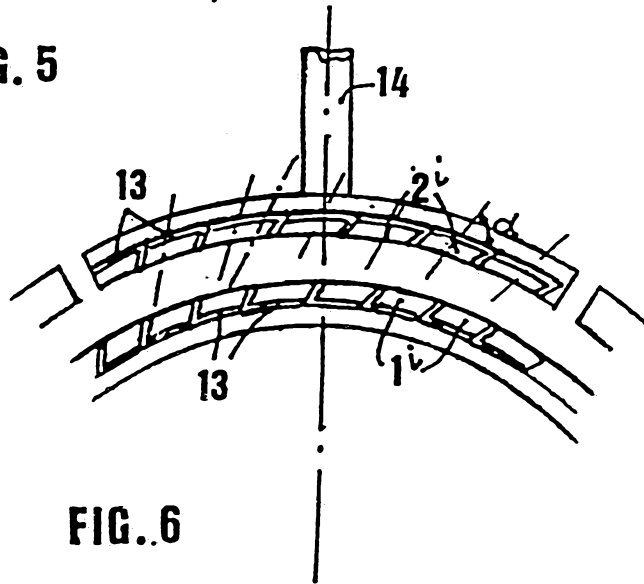


FIG. 6

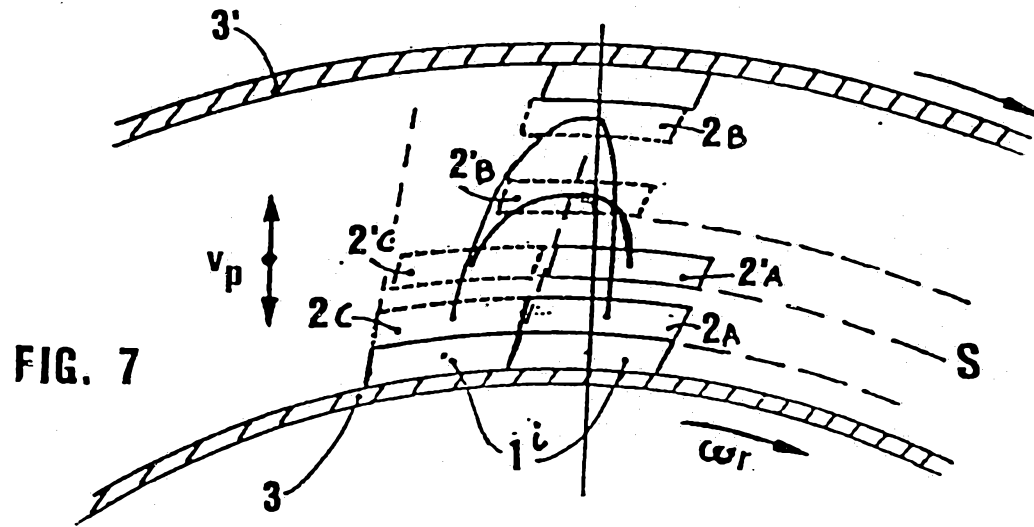


FIG. 7

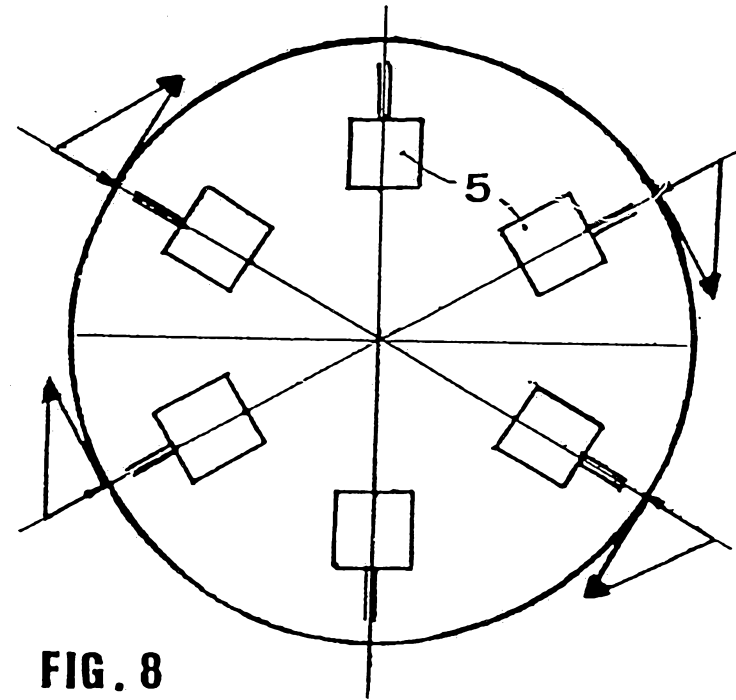


FIG. 8

FIG.10

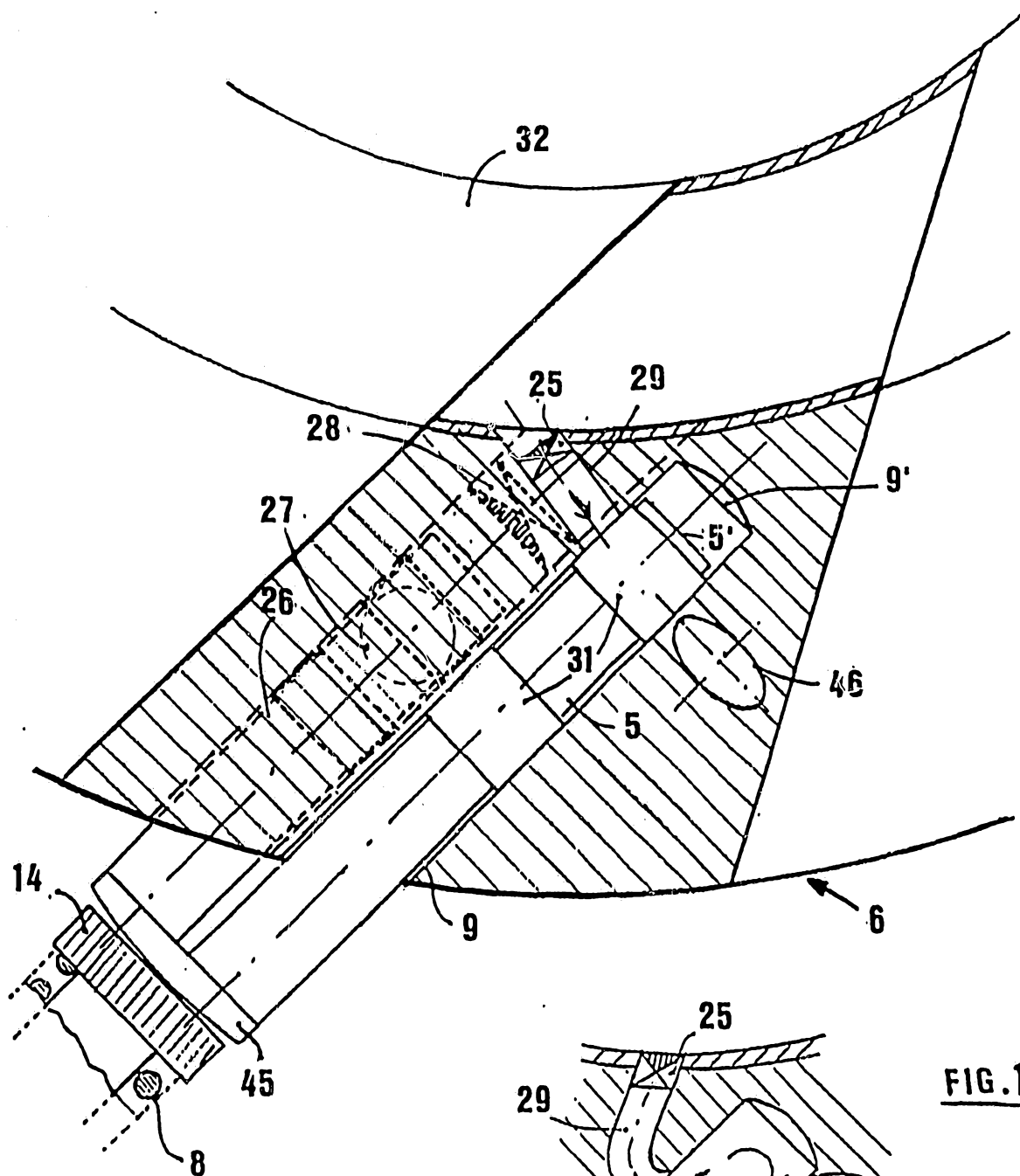


FIG. 11

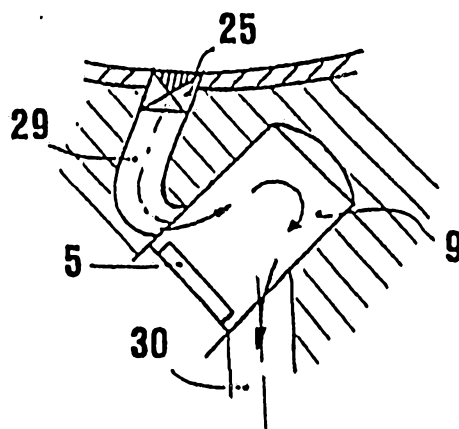


FIG. 12

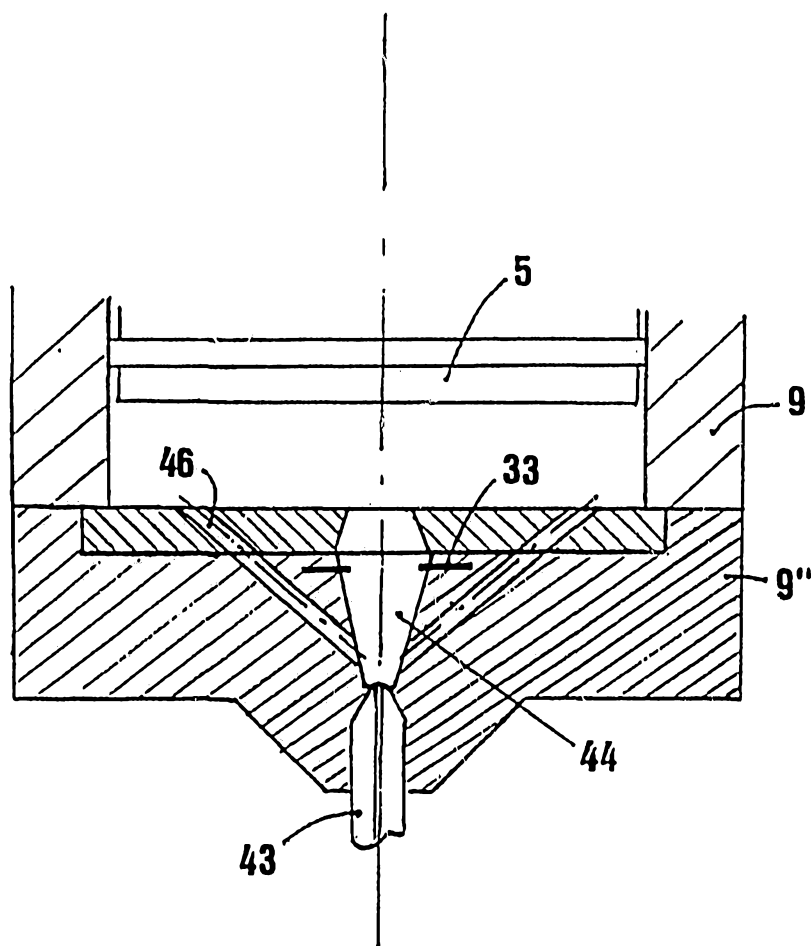
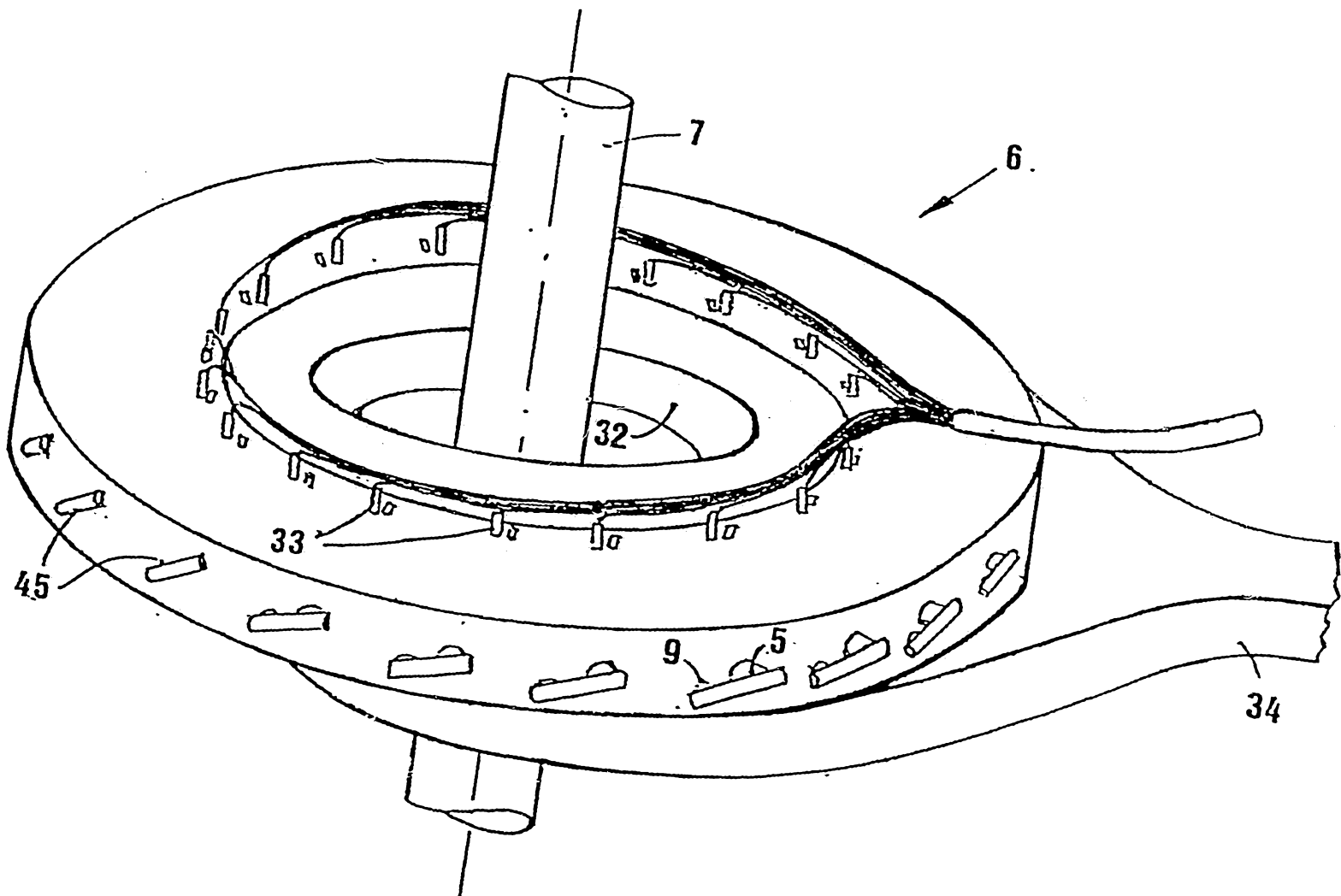


FIG. 13



SUBSTITUTE SHEET

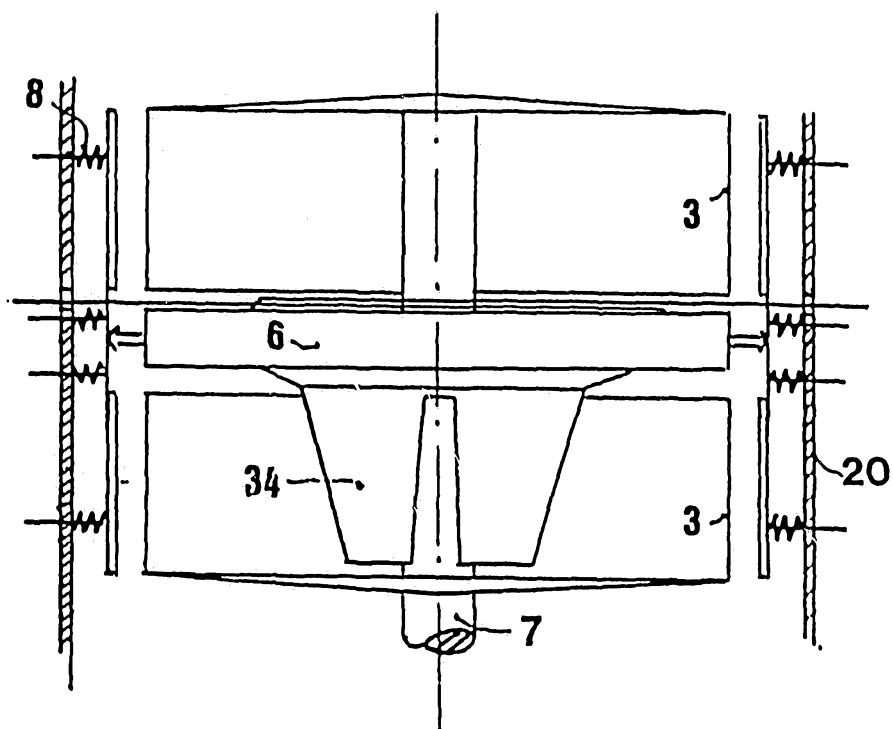


FIG. 14

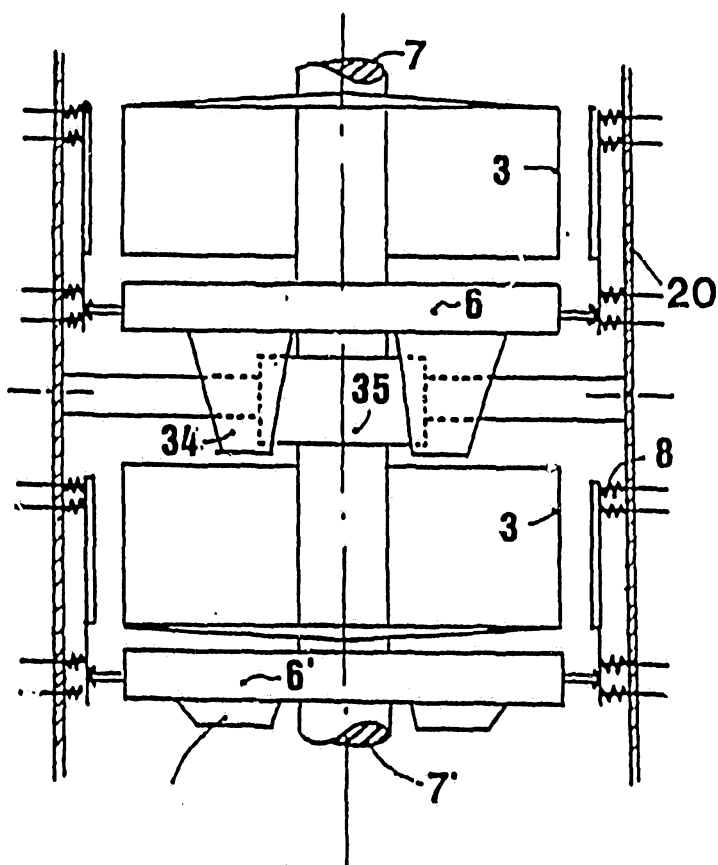
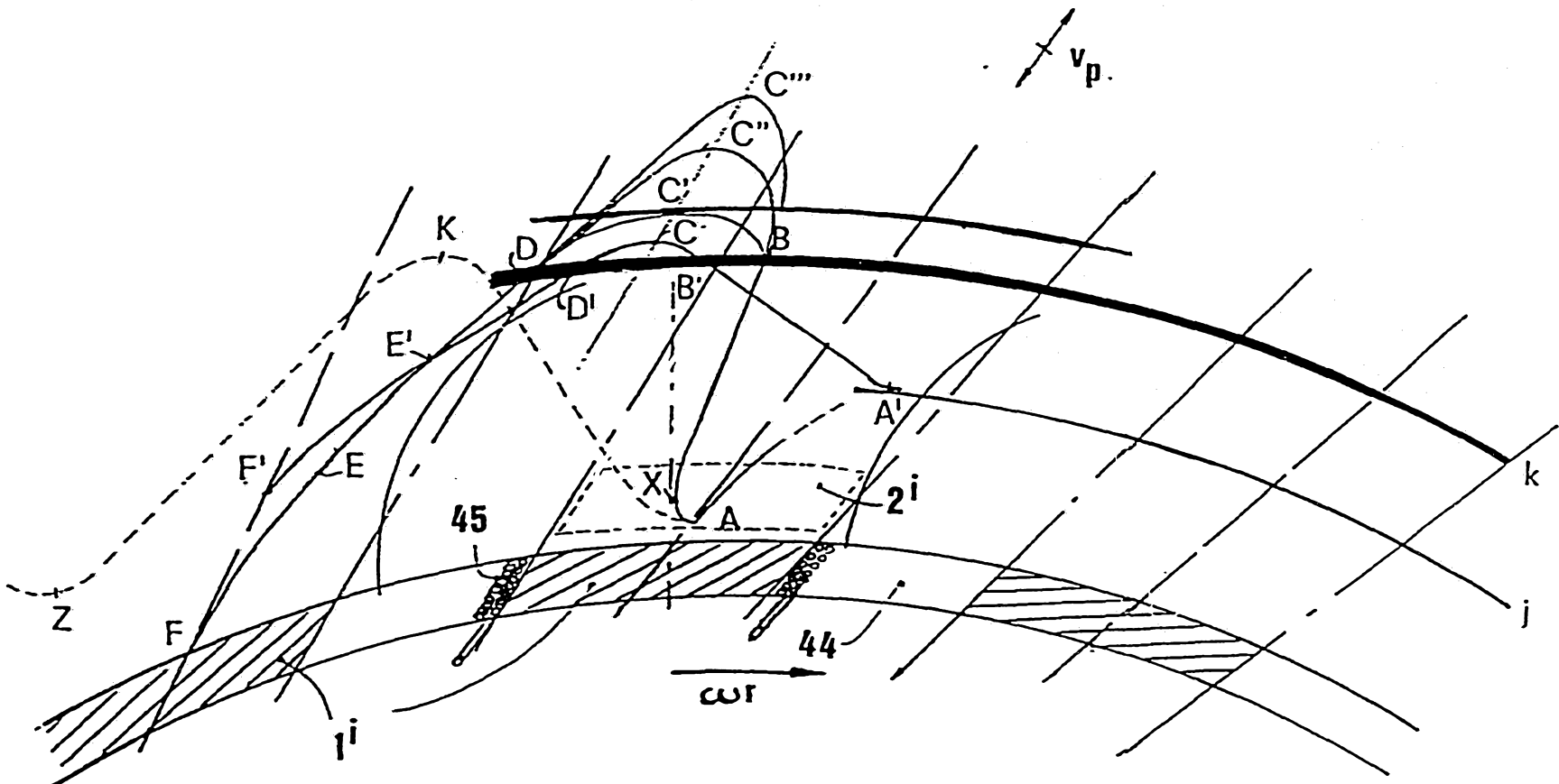
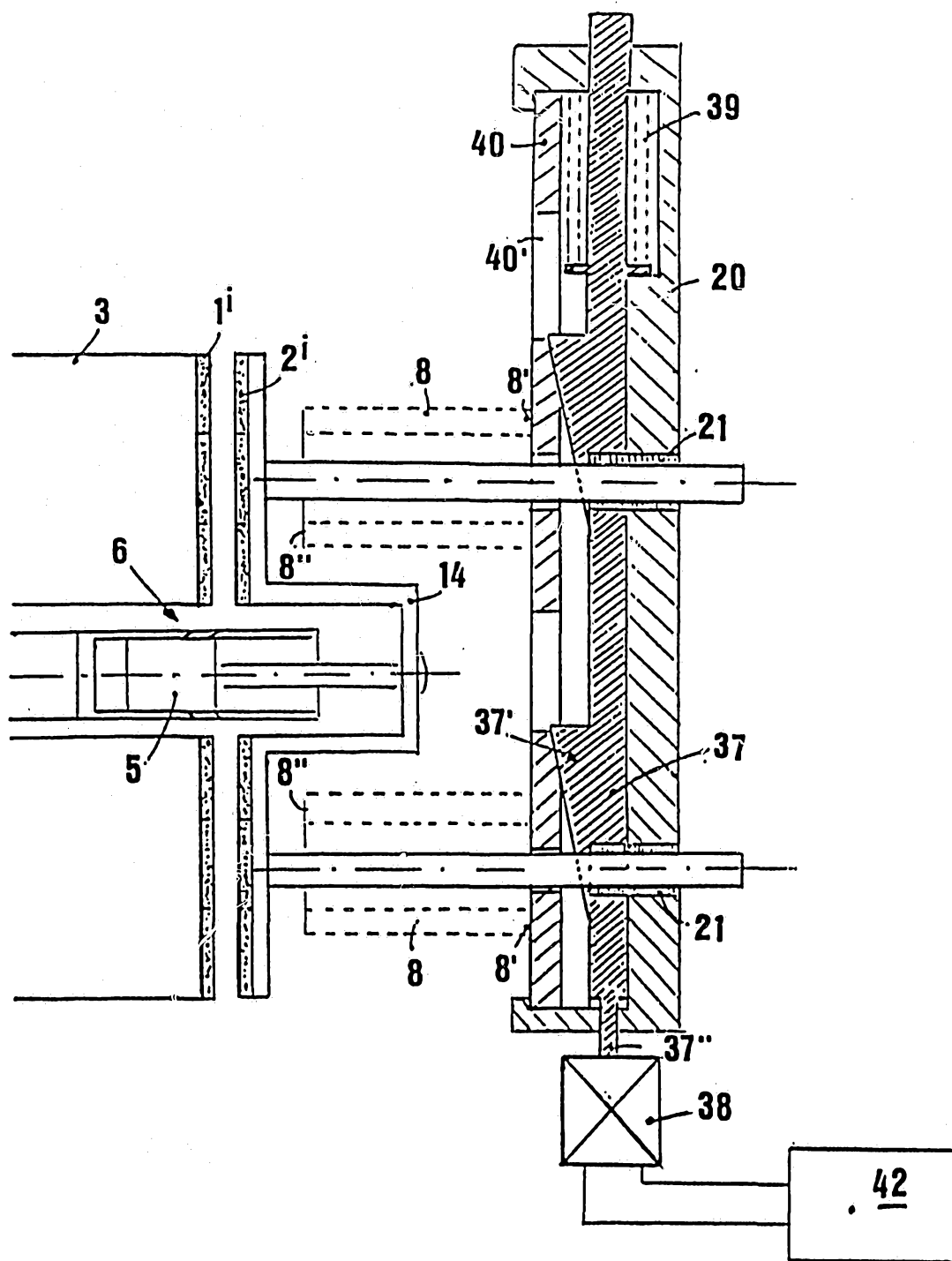


FIG. 15

FIG. 16



FIG. 17

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 92/01462

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all)⁶

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 H02K49/10; F02B75/32

II. FIELDS SEARCHED

Minimum Documentation Searched⁷

Classification System	Classification Symbols
Int.Cl. 5	H02K ; F02B ; F01B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched⁸III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹

Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	EP,A,0 152 252 (UNI COM) 21 August 1985 see page 15, line 4 - page 17, line 14; figures	1,3,5, 18,24
Y		2,4,6-9, 14-17 19
A		
Y	GB,A,747 682 (MUIRHEAD & CO) 11 April 1956 see page 1, line 14 - line 18 see line 59 - line 65 see line 73 - line 79 see page 2, line 1 - line 6	2
	-/--	

¹⁰ Special categories of cited documents:

- "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

"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.

"A" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

23 SEPTEMBER 1992

Date of Mailing of this International Search Report

05.10.92

International Searching Authority

EUROPEAN PATENT OFFICE

Signature of Authorized Officer

ZANICHELLI F.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category ^a	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	US,A,3 992 132 (PUTT) 16 November 1976 see column 2, line 33 - column 5, line 23; figures 1-4	1
Y		4
A		3
Y	FR,A,2 307 132 (GUILLON) 5 November 1976 see the whole document	6-9, 17
A		10-13
Y	GB,A,2 219 671 (J. F. KOS) 13 December 1989	14-16
A	US,A,4 794 901 (HONG ET AL.) 3 January 1989	6-11

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO. EP 9201462
SA 61909**

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		JP-A- 60223467	07-11-85
		AU-A- 3861685	15-08-85

GB-A-747682		None	

US-A-3992132	16-11-76	None	

FR-A-2307132	05-11-76	None	

GB-A-2219671	13-12-89	DE-A- 3913806	09-11-89
		JP-A- 1313634	19-12-89
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