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(Under International Convention.)

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cation (in the United States),*

Date of Application (in the United Kingdom), 17th Oct., 1910

At the expiration of twelve months from the date of the first Foreign Application, the provision of Section 91 (3) (a) of the Patents and Designs Act, 1907, as to inspection of Specification, became operative

Accepted, 6th July, 1911

COMPLETE SPECIFICATION.

Improved Method of Imparting Energy to or Deriving Energy from a Fluid and Apparatus for use therein.

I, NIKOLA TESLA, Engineer, residing at the Waldorf-Astoria, corner 34th Street and Fifth Avenue, Borough of Manhattan, City and State of New York, U.S.A., do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

In the practical application of mechanical power based on the use of a fluid as vehicle of energy it has been demonstrated that, in order to attain the highest economy, the changes in velocity and direction of movement of the fluid should be as gradual as possible. In the present known forms of such apparatus the fluid has always been guided or restrained more or less gradually but nevertheless restrained in its actual direction of flow, so that it followed some previously determined path. Attempts have been made to minimise shock as much as possible but no one seems to have conceived the idea of allowing the fluid to follow an entirely unrestrained path in its direction of motion so that shocks and vibrations and friction losses were unavoidable. Besides, the employment of the usual devices for imparting energy to, or deriving energy from a fluid, as pistons, paddles, vanes and blades, necessarily introduces numerous defects and limitations and adds to the complication, cost of production and maintenance of the machines.

The object of my invention is to overcome these deficiencies and to effect the transmission and transformation of mechanical energy through the agency of fluids in a more perfect manner, and by means simpler and more economical than those heretofore employed.

I accomplish this by allowing the propelled or propelling fluid to move in natural paths or stream lines of least resistance which are not determined by guiding or retaining surfaces such as vanes or kindred devices, interposed in the path of motion of the fluid and to change its velocity and direction of movement by imperceptible degrees, thus avoiding the losses due to sudden variations while the fluid is receiving or imparting energy. The only artificial restraint I propose to place on the fluid is restraint in a direction at right angles or substantially at right angles to its direction of motion.

It is well known that a fluid possesses, among others, two salient properties;

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adhesion and viscosity. Owing to these a body propelled through such a medium encounters a peculiar impediment known as "lateral" or "skin resistance" which is two-fold; one arising from the shock of the fluid against the asperities of this solid substance, the other from internal forces opposing molecular separation. As an inevitable consequence a certain amount of the fluid is dragged along by the moving body. Conversely, if the body be placed in a fluid in motion, for the same reasons, it is impelled in the direction of movement.

These effects, in themselves, are of daily observation, but I believe that I am the first to apply them in a practical and economical manner of fluid propulsion. The nature of my discovery and the principles of construction of the apparatus which I have designed for carrying it out, I shall now proceed to describe by reference to the accompanying drawings which illustrate an operative and efficient embodiment of the same.

Fig. 1 is a partial end view, and Fig. 2 a vertical cross section of a pump or compressor, which Figs. 3 and 4 represent, respectively, in corresponding views, a rotary engine or turbine, both machines being constructed and adapted to be operated in accordance with my invention.

Figs. 1 and 2 show a runner composed of a plurality of flat rigid disks 1 of a suitable diameter, keyed to a shaft 2 and held in position by a threaded nut 3, a shoulder 4 and washers 5 of the requisite thickness. Each dish has a number of central openings 6, the solid portions between which form spokes 7 preferably curved, as shown, for the purpose of reducing the loss of energy due to the impact of the fluid.

This runner is mounted in a two-part volute casing 8 having stuffing boxes 9 and inlets 10 leading to its central portion. In addition a gradually widening and rounding outlet 11 is provided formed with a flange for connection to a pipe as usual. The casing 8 rests upon a base 12 shown only in part and supporting the bearings for the shaft 2, which being of ordinary construction are omitted from the drawings.

An understanding of the principle embodied in this device will be gained from the following description of its mode of operation.

Power being applied to the shaft and runner set in rotation in the direction of the solid arrow, the fluid by reason of its properties of adherence and viscosity, upon entering through the inlets 10 and coming in contact with the disks 1 is taken hold of by the same and subjected to two forces, one acting tangentially in the direction of rotation, and the other radially outward. The combined effect of these tangential and centrifugal forces is to propel the fluid, with continuously increasing velocity in a spiral path until it reaches the outlet 11 from which it is ejected. This spiral movement, free and undisturbed and essentially dependent on these properties of the fluid, permitting it to adjust itself to natural paths or stream lines and to change its velocity and direction by insensible degrees, is characteristic of this method of propulsion and advantageous in its application.

While traversing the chamber enclosing the runner, the particles of the fluid may complete one or more turns, or but a part of one turn. In any given case their path can be closely calculated and graphically represented, but fairly accurate estimates of turns can be obtained simply by determining the number of revolutions required to renew the fluid passing through the chamber and multiplying it by the ratio between the mean speed of the fluid and that of the disks.

I have found that the quantity of fluid propelled in this manner is, other conditions being equal, approximately proportionate to the active surface of the runner and to its effective speed. For this reason, the performance of such machines augments at an exceedingly high rate with the increase of their size and speed of revolution.

The dimensions of the device as a whole, and the spacing of the disks in any given machine will be determined by the conditions and requirements of special

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cases. It may be stated that the intervening distance should be the greater, the larger the diameter of the disks, the longer the spiral path of the fluid and the greater its viscosity. In general, the spacing should be such that the entire mass of the fluid, before leaving the runner, is accelerated to a nearly uniform velocity, not much below that of the periphery of the disks under normal working conditions and almost equal to it when the outlet is closed and the particles moved in concentric circles.

It may also be pointed out that such a pump can be made without openings and spokes in the runner, as by using one or more solid disks, each in its own 10 casing, in which form the machine will be eminently adapted for sewage, dredging and the like, when the water is charged with foreign bodies and spokes or vanes especially objectionable.

Another application of this principle which I have discovered to be not only feasible, but thoroughly practicable and efficient, is the utilization of machines 15 such as above described for the compression or rarefaction of air, or gases in general. In such cases it will be found that most of the general considerations obtaining in the case of liquids, properly interpreted, hold true.

When, irrespective of the character of the fluid, considerable pressures are desired, staging or compounding may be resorted to in the usual way the 20 individual runners being, preferably, mounted on the same shaft.

The principles underlying the invention are capable of embodiment also in that field of mechanical engineering which is concerned in the use of fluids as motive agents, for while in some respects the actions in the latter case are directly opposite to those met with in the propulsion of fluids, the fundamental 25 laws applicable in the two cases are the same. In other words, the operation above described is reversible, for if water or air be admitted under pressure to the opening 11 the runner is set in rotation in the direction of the dotted arrow by reason of the peculiar properties of the fluid which, travelling in a spiral path and with continuously diminishing velocity, reaches the orifices 6 and 10 30 through which it is discharged. If the runner be allowed to turn freely, in nearly frictionless bearings, its rim will attain a speed closely approximating the maximum of that of the fluid in the volute channel and the spiral path of the particles will be comparatively long, consisting of many almost circular turns. If load is put on and the runner slowed down, the motion of the fluid 35 is retarded, the turns are reduced, and the path is shortened.

Owing to a number of causes affecting the performance it is difficult to frame a precise rule which would be generally applicable, but it may be stated that within certain limits, and other conditions being the same, the torque is directly proportionate to the square of the velocity of the fluid relatively to the runner 40 and to the effective area of the disks and, inversely, to the distance separating them. The machine will, generally, perform its maximum work when the effective speed of the runner is one half of that of the fluid. But to attain the highest economy the relative speed or slip, for any given performance, should be as small as possible. This condition may be to any desired degree approximated by increasing the active area and reducing the space between the disks.

When apparatus of the kind described is employed for the transmission of power certain departures from similarity between transmitter and receiver may be necessary for securing the best results. It is evident that, when transmitting power from one shaft to another by such machines, any desired ratio between 50 the speeds of rotation may be obtained by proper selection of the diameters of the disks, or by suitably staging the transmitter, the receiver, or both. But it may be pointed out that in one respect, at least, the two machines are essentially different. In the pump, the radial or static pressure, due to centrifugal force, is added to the tangential or dynamic, thus increasing the effective head and assisting in the expulsion of the fluid. In the motor, on the contrary, the first named pressure, being opposed to that of supply, reduces the effective head and the velocity of radial flow towards the center. Again, in the propelled

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machine a great torque is always desirable, this calling for an increased number of disks and smaller distance of separation, while in the propelling machine, for numerous economic reasons, the rotary effect should be the smallest and the speed the greatest practicable. Many other considerations, which will naturally suggest themselves, may affect the design and construction, but the preceding is thought to contain all necessary information in this regard.

The greatest value of this invention will be found in its use for the thermodynamic conversion of energy. Reference is now made to Figs. 3 and 4, illustrative of the manner in which it is, or may be, so applied.

As in the previous figures, a runner is provided made up of disks 13 with openings 14 and spokes 15 which, in this case may be straight. The disks are keyed to and held in position on a shaft 16, mounted to turn freely in suitable bearings, not shown, and are separated by washers 17 conforming in shape with the spokes and firmly united thereto by rivets 18. For the sake of clearness but a few disks, with comparatively wide intervening spaces, are indicated.

The runner is mounted in a casing comprising two end castings 19 with outlets 20 and stuffing boxes 21, and a central ring 22, which is bored out to a circle of a diameter slightly larger than that of the disks, and has flanged extensions 23 and inlets 24 into which finished ports, or nozzles, 25 are inserted. Circular grooves 26 and labyrinth packings 27 are provided on the sides of the runner. Supply pipes 28, with valves 29, are connected to the flanged extensions of the central ring one of the valves being, normally, closed.

With the exception of certain particulars, which will be hereinafter elucidated, the mode of operation will be understood from the preceding description. Steam or gas under pressure being allowed to pass through the valve at the side of the solid arrow, the runner is set in rotation in clockwise direction.

In order to bring out a distinctive feature assume, in the first place, that the motive medium is admitted to the disk chamber through a port, that is, a channel which it traverses with nearly uniform velocity. In this case, the machine will operate as a rotary engine, the fluid continuously expanding on its tortuous path to the central outlet. The expansion takes place chiefly along the spiral path, for the spread inward is opposed by the centrifugal force due to the velocity of whirl and by the great resistance to radial exhaust. It is to be observed that the resistance to the passage of the fluid between the plates is, approximately proportionate to the square of the relative speed, which is maximum in the direction towards the center and equal to the full tangential velocity of the fluid. The path of least resistance, necessarily taken in obedience to a universal law of motion is, virtually, also that of least relative velocity.

Next, assume that the fluid is admitted to the disk chamber not through a port, but a diverging nozzle, a device converting wholly or in part, the expansive into velocity-energy. The machine will then act rather like a turbine, absorbing the energy of kinetic momentum of the particles as they whirl, with continuously decreasing speed, to the exhaust.

The above description of the operation, I may add, is suggested by experience and observation, and is advanced merely for the purpose of explanation. The undeniable fact is that the machine does operate, both expansively and impulsively. When the expansion in the nozzle is complete, or nearly so, the fluid pressure in the peripheral clearance space is small; as the nozzle is made less divergent and its section enlarged, the pressure rises, finally approximating that of the supply. But the transition from purely impulsive to expansive action may not be continuous throughout, on account of critical states and conditions and comparatively great variations of pressure may be caused by small changes of nozzle velocity.

In the preceding it has been assumed that the pressure of supply is constant or continuous, but it will be understood that the operation will be, essentially, the same if the pressure be fluctuating or intermittent, as that due to explosions occurring in more or less rapid succession.

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A very desirable feature, characteristic of machines constructed and operated in accordance with this invention, is their capability of reversal of rotation. Fig. 3, while illustrative of a special case, may be regarded as typical in this respect. If the right hand valve be shut off and the fluid supplied through the second pipe, the runner is rotated in the direction of the dotted arrow the operation, and also the performance, remaining the same as before, the central ring being bored to a circle with this purpose in view. The same result may be obtained in many other ways by specially designed valves, ports or nozzles for reversing the flow, the description of which is omitted here in the interest of simplicity and clearness. For the same reasons but one operative port or nozzle is illustrated which might be adapted to a volute but does not fit best a circular bore. It will be understood that a number of suitable inlets may be provided around the periphery of the runner to improve the action and that the construction of the machine may be modified in any ways.

Still another valuable and probably unique quality of such motors or prime movers may be described. By proper construction and observance of working conditions the centrifugal pressure, opposing the passage of the fluid, may, as already indicated, be made nearly equal to the pressure of supply when the machine is running idle. If the inlet section be large, small changes in the speed of revolution will produce great differences of flow which are further enhanced by the concommittant variations in the length of the spiral path. A self-regulating machine is thus obtained bearing a striking resemblance to a direct current electric motor in this respect that, with great differences of impressed pressure in a wide open channel the flow of the fluid through the same is prevented by virtue of rotation. Since the centrifugal head increases as the square of the revolutions, or even more rapidly, and with modern high grade steel great peripheral velocities are practicable, it is possible to attain that condition in a single stage machine, more readily if the runner be of large diameter. Obviously this problem is facilitated by compounding, as will be understood by those skilled in the art. Irrespective of its bearing on economy, this tendency, which is, to a degree, common to motors of the above description, is of special advantage in the operation of large units, as it affords a safeguard against running away and destruction.

Besides these, such a prime mover possesses many other advantages, both constructive and operative. It is simple, light and compact, subject to but little wear, cheap and exceptionally easy to manufacture as small clearances and accurate milling work are not essential to good performance. In operation it is reliable, there being no valves, sliding contacts or troublesome vanes. It is almost free of windage, largely dependent of nozzle efficiency and suitable for high as well as for low fluid velocities and speeds of revolution.

It will be understood that the principles of construction and operation above generally set forth, are capable of embodiment in machines of the most widely different forms, and adapted for the greatest variety of purposes. In my present application I have sought to describe and explain only the general and typical applications of the principle which I believe I am the first to realize and turn to useful account.

I am aware that it has already been proposed to effect atomising by dropping a liquid on to a plate rotating about a substantially vertical axis and I make no claim to the arrangement.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. The method of imparting energy to, or deriving it from a fluid consisting in bringing the fluid in contact with rotary surfaces where, by its natural properties of adhesion and viscosity, it is, under the action of tangential and radial

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forces, free to follow its natural curved path, either radially outwards to the periphery or radially inwards to the axis of the rotating surfaces.

2. Apparatus for carrying out the method claimed in Claim 1, having one or several rotary discs mounted in a casing to which fluid is admitted centrally and allowed to follow its natural curved or spiral path between the separate discs or between the discs and casing consequent upon the radial and tangential forces acting thereon, said fluid being then allowed to pass off from an opening or passage leading from the periphery of the casing, substantially as set forth. 5

3. Apparatus for carrying out the process claimed in Claim 1, having one or several rotary discs mounted in a casing to which fluid is admitted circumferentially and substantially tangentially to the motion of the discs, said fluid being allowed under all conditions of loading to follow its natural curved or spiral path between the discs and casing consequent upon the radial and tangential forces reacting thereon and being subsequently withdrawn or exhausted substantially centrally. 10

4. Apparatus as claimed in Claim 3, characterised by nozzles for transforming the pressure energy of the fluid into velocity energy prior to its passing into contact with the discs, whereupon the velocity of the fluid is reduced gradually as it proceeds in its curved or substantially spiral path. 15

5. Apparatus as claimed in Claims 3 or 4, having two sets of nozzles or members for directing the stream of fluid on the rotary members, said sets being arranged to produce rotation in opposite directions and means for making one or other of said sets operative as desired, substantially as described. 20

6. The improved method of extracting energy from fluids or imparting energy thereto hereinbefore described and the apparatus for carrying out said method as hereinbefore described or illustrated in the accompanying drawings. 25

Dated this 17th day of October, 1910.

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Reference has been directed in pursuance of Section 7, Sub-section 4, of the Patents and Designs Act, 1907, to Specification No. 696 of 1867. 30

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