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PATENT SPECIFICATION

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Complete not Accepted.

COMPLETE SPECIFICATION.

An Improved Internal Combustion Turbine and Turbo-propeller.

I, FRANK ATHERTON HOWARD, citizen of the United States of America, residing at 183, Stiles Street, Elizabeth, New Jersey, United States of America, 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:—

My invention relates to internal combustion turbines and turbo-propellers.

The gas turbine of the present invention is characterised by its simplicity, reliability, light weight, low cost, and absence of torque reaction. These advantages make it particularly suitable as a motor for aircraft, avoiding difficulties which are inherent in other forms of motors and permitting new arrangements which constitute important advances in the aviation art. Among the most important of these arrangements is the structural union of propeller and turbine to form a turbo-propeller.

It furthermore lends itself readily to a novel arrangement of especial value for driving dynamo electric machines. Numerous other advantageous applications of the turbine in the above and other arts will become apparent when the principles of the machine are known to those skilled in such arts.

According to my invention the improved explosion reaction turbine comprises a rotor adapted to operate at a peripheral velocity of at least about one thousand feet per second, an explosion type combustion chamber carried by the rotor, means for repeatedly and with extreme rapidity supplying charges of explosive gases to said chamber means for igniting the gases only when the chamber is substantially filled, means for confining the ignited gases whereby their heat energy is converted into pressure energy, an expansion tube of relatively small diameter opening from the chamber through which the confined high pressure gases escape at a relatively mean velocity of discharge of the order of but greater than the peripheral speed of the rotor, whereby the pressure energy of the charge is converted into kinetic energy of the escaping gas stream, said expansion tube being carried to a point adjacent to the periphery of the rotor, and there discharging the gases tangentially in a direction opposite to that of rotation, whereby the absolute velocity and heat energy content of the released explosion gases is greatly reduced at the expense of the useful work performed in the rotor. The gaseous charge is advantageously supplied by the high centrifugal force engendered of the high peripheral velocity of the rotor.

The combustion chamber is advantageously mounted on the rotor at a point well within its periphery, whereby the rotor structure is relieved of the high centrifugal strains which would result from carrying the chamber at the periphery.

The accompanying drawings illustrate diagrammatically various embodiments of the invention.

In these drawings:

Figure 1 is a longitudinal section through a combustion chamber of the continuous type;

Figure 2 is a transverse section on the line I—I of Figure 1;

Figure 3 is a broken longitudinal section showing a single stage ejector type of nozzle;

Figure 4 is an enlarged section of an igniter plug;

Figure 5 is a broken section through the base of an explosion type chamber showing the admission ports and valves;

Figure 6 is an elevation of the end of the chamber shown in Figure 5.

Figure 7 is a longitudinal section of an explosion type chamber provided with an automatic cut-off.

Figure 8 is an axial section through a turbine embodying one form of my invention;

Figure 9 is an axial section through another form of turbine especially useful for the driving of dynamo electrical machines;

Figure 10 is an enlarged broken detail elevation of the rim of the turbine shown in Figure 9, as viewed from the left;

Figure 11 is a broken axial section of a turbine rotor, showing means which may be employed for supplying separately two gases to the rim of the rotor, for separately delivering the same to combustion chambers carried thereby:

Figure 12 is a plan view of a turbo-propeller consisting of a propeller or revolving wing having combustion chambers mounted therein for driving;

Figure 13 is a transverse section through the upper blade of Figure 12 showing the combustion chamber;

Figure 14 is a plan view of a turbo-propeller carrying a series of combustion chambers on its rim: Figure 15 is a section on the line I—I of Figure 14 showing the partition web in the hollow blade;

Figure 16 is a section through the rim taken on the line II—II of Figure 14;

Figure 17 is a plan view of a turbo-propeller having radially arranged combustion chambers;

Figure 18 is an enlarged broken section through the rotor showing the mounting of the combustion chambers and their valves;

Figure 19 is a section on the line I—I of Figure 17;

Figure 19a is a similar section of a modified construction;

Figure 20 is an enlarged broken section, partly in elevation, through the rim of a rotor showing a muffler construction;

Figure 21 is a diagrammatic view of the turbo-propeller of Figure 14 applied to a conventional bi-plane.

Figure 22 is a diagrammatic section of a helicopter employing the turbo-propeller of Figure 14;

Figure 23 is a transverse section through the nacelle of the helicopter shown in Figure 22.

Referring first to Figure 1, there is illustrated a cylindrical combustion chamber 1 formed by a metallic shell 2, lined with a refractory material 3 of some insulating value. The shell is cooled by longitudinal fins 4 of metal joined to the shell in heat-conducting relationship. Fuel gas, for example a mixture of 1 part by weight of gasoline vapour in 5 parts of air, is supplied under pressure to the base of the chamber by a pipe 5, and air for combustion is likewise supplied by a pipe 6. Ignition is effected initially by an igniter plug 7 in the wall of the chamber. Combustion within the chamber raises the temperature of the gases entering the same to a point depending upon the pressure of the supply, the heating value of the gas, and the heat losses through the wall of the chamber. The heat energy liberated causes expansion of the gas directly, which expansion would of itself increase the velocity of exit of the gases from the chamber. Further increase of velocity with resultant absorption of heat energy is preferably obtained by causing the exit gases leaving the throat 8 of the chamber to emerge through an outwardly tapering nozzle 9, the length and angularity of which determine the efficiency of the conversion of the heat energy into velocity. The rate of discharge of the gases (mass discharged per second) multiplied by a velocity of efflux (relative to the chamber) determines the reaction upon the chamber, this reaction impulse being equal in amount and opposite in direction to the momentum of the gas leaving the system. The heat content of the exit gases is in any case a direct energy loss. The other source of energy loss is the absolute velocity of the exit gas. This latter source of energy loss is in part converted into useful work by my invention by permitting the combustion chamber and its nozzle to move in the direction of the applied force of reaction. To the extent that the velocity of such movement approaches the relative velocity of exit of the gas, the absolute velocity of the latter and the consequent energy loss is reduced at the expense of the useful work accomplished by the forcible movement of the chamber. The means by which this principle is utilised will appear hereafter.

In many cases it is impractical to obtain an absolute velocity of the rotor which is high as compared with the relative velocity of the exit gases. This is particularly true with the explosion type combustion chamber hereafter described. In such cases I may employ a further improvement, that is, cause the exit gases to entrain a stream of air in an ejection nozzle. While this step in itself results in some waste of energy, the loss may be more than offset by the gain in efficiency which results from the decreased velocity of the mixed stream. A structural advantage also results in that the exit gases are instantaneously cooled by admixture with the entrained air, and thus the whole mass of expelled material is reduced in temperature to a point which avoids necessity of external cooling to hold the shell of the nozzle below a softening temperature.

Another view of the physics of the ejector type nozzle is that it retards the outflow of gas directly from the combustion chamber without decrease of the cross-section of the stream, and pro tanto increases the time during which the reaction force is effective, thereby raising the value of the impulse, the latter being a product of force and time.

In place of the continuous combustion type of chamber heretofore described I may employ an intermittent combustion chamber of the explosion type. Such chambers require to be equipped with one-way valves for the entrances of gaseous fuel and air either together or separately. In Figures 3 to 7 inclusive I have illustrated two forms of explosion chamber. The chamber itself, designated 10 may be of the same form as the continuous combustion chamber, save that it does not reach such a high mean temperature and therefore may be simplified by the omission of the refractory lining; and even the cooling fins in appropriate cases. The igniter plug 7 is located near the throat 8 in order that the fresh gases entering the base of the chamber may push ahead of them the residual combustion gas before reaching the igniter.

In place of the simple expanding nozzle 9 I may use an ejector type nozzle having an air tube 9a surrounding the tip of the nozzle to cause the entrainment of a stream of air which enters through the annular space between the nozzle and the tube. This construction is of particular value in the case of large explosion chambers of low heat loss in which the internal pressure on explosion rises to a high figure with resultant increased velocity of exit of the gases from the chamber. In place of the single stage ejector illustrated I may use multiple stage ejectors of known design.

I prefer to use a hot wire type of igniter plug of the form illustrated in Figure 4, although a conventional spark plug may be employed. The hot wire igniter consists of a body 11 tapped into the shell 2 and carrying a refractory insulator 12 through which are led conductors 13 terminating in balls 14. Between the balls 14 extends a short resistance wire 15 which is raised to a high temperature by the passage of a low potential electrical current. The balls 14 serve not only as attachments for the resistance wire but as heat retaining elements which operate as ignition points by their residual heat when the chamber has been in operation for a short time, thus permitting the current to be cut off and extending the useful life of the resistance wire.

In Figures 5 and 6 I have shown in detail the one-way valves which are employed in the base of the explosion chamber. These are spring-loaded check valves. It is required that they operate automatically and extremely fast under the alternating variations of pressure within the chamber and for that reason it is essential that they have the minimum of inertia, the minimum of motion, the minimum of friction, and the maximum free area. It is further required that their action be uninfluenced by centrifugal force, as will later appear. In Figures 5 and 6 these conditions are met by the use of multiple valves, designated 16, each having a thin disc serving as a head, carried by an arm 17 pivoted at 18 on the base of the chamber. Springs 19 between the arms 17 and the base hold the valves normally against their seats. In order to avoid all danger of back-fire and at the same time obtain the requisite instantaneous mixing of the gaseous fuel and air in the chamber I may supply the fuel gas and air to separate ports in the base of the chamber. Thus the air may enter through the main or central ports 20 and the fuel gas through annular ports 21 surrounding the air ports and supplied through ducts 22 in the base communicating with an annular channel 23 to which the fuel gas is supplied by means not shown. It will be noted that the base of the chamber is enlarged in diameter at the point 24 in order to accommodate the maximum number of valves of the maximum size. The arrow marked C—F in Figure 6 and in Figure 7 shows the direction of the centrifugal force acting upon the chamber and valves, as will later appear. It is here to be noted that the direction of motion of the valves is at right angles to this force, i.e. in a tangent plane and hence uninfluenced thereby save to the extent of the increased load and friction on the pivots 18.

The explosion chamber of Figures 3 to 6 inclusive operate as follows: Assuming air and fuel gas to be supplied under some pressure exceeding that existing in the chamber, the valves 16 open against the resistance of the loading springs 19 and admit the two gases which become intimately mixed in the act of entrance through the arrangement of the ports. Further, the mixture results from the turbulence attained by the enlarged form of base. The combustible mixture progresses forwardly towards the throat 8, sweeping ahead the gases already present.

When the mixture column reaches the igniter 7 it is fired. The resultant combustion raises the temperature and pressure within the chamber, causing the valves 16 to shut. The gas passes out through the throat 8 and nozzle 9, if the latter be employed. When the expansion of the gas has been completed and the pressure returns to a point below that of the inlet gases, the valves again open and the cycle is repeated. The time required to complete a cycle is dependent upon many factors but may be as little as one-fortieth part of a second. High pressure of supply, quick valve action, and large valve areas are the essentials of rapid operation in large chambers.

In Figure 7 I have illustrated a simple type of explosion chamber in which the combustible mixture is supplied through a single poppet-type check valve 25 through a pipe 26. In order to prevent back-firing a screen 27 may be inserted in the mixture inlet pipe 26.

I may also employ a safety cut-off valve in the form of a butterfly throttle valve 26a, the actuating arm of which is pulled toward the closed position by a spring 26b. This valve is normally held open by a wire 26c which is soldered or welded to the shell of the chamber with material which softens below the softening point of the shell itself; for example, a brass solder may be used. The shell of the chamber on the other hand should be constructed of a metal which maintains its tensile strength at high temperatures; for example, an alloy of steel containing 18% chromium, 8% nickel and .07 carbon. By virtue of this construction the chamber may safely run at an efficient high shell temperature nearly up to the self-ignition point of the charge, while danger of burning out is overcome by the automatic closing of the cut-off valve when the shell temperature exceeds the softening point of the brass solder employed for fastening the wire 26c. The use of the alloy specified for the shell is in all cases of advantage since it permits of running the chamber at the most efficient temperature. The cut-off valve is particularly useful where the chamber is used on a turbo-propeller for aircraft.

In Figure 8 I have illustrated the first complete turbine construction. This consists of a stationary base 28, which carries a hollow stationary shaft 29, the bore of which communicates through holes 30 with a cavity 31 in the base. A carburettor 32 designed to supply a rich mixture of gasoline vapour in air communicates with the cavity 31 for supplying thereto, thence to the shaft, a fuel gas too rich for explosion. The carburettor has the usual throttle 33.

The projecting end of the hollow shaft 29 carries on suitable bearings the turbine rotor 34, which here takes the form of a hollow drum carrying a stub-shaft 35, from which the power is delivered. At a point within the drum 34 the shaft 29 has openings 36, which are encased by a revolving hollow hub 37 attached to the rotor. From the hub 37 radiate gas delivery pipes 38, each of which at its outer end supplies the base of a combustion chamber 1, which may be of either the continuous or explosion type heretofore described.

The chambers 1 are carried by the walls of the drum and are disposed at an acute angle with reference to the plane of rotation in planes at right angles to the respective radial gas delivery pipes. The former relationship is apparent from the chamber lying directly behind the shaft 29, and the latter by the chambers at the top and bottom of the view. The top chamber is shown entirely in longitudinal section although the section plane is not parallel with the plane of the paper but rather inclined away from it toward the right.

Each chamber opens through the drum side-wall at its inlet end, the drum carrying air-scoops 39 which direct against the base of the chamber a stream of air engendered of the revolution of the drum. The nozzle of each chamber projects through the opposite wall of the drum for delivery into the atmosphere of the stream of high velocity combustion gas.

A battery 40 connects with a slip-ring 41, thence by individual leads 42 with the igniter plugs 7, which in this instance may have each one terminal grounded to the machine.

Ports 43 in the side wall of the drum admit cooling air which escapes through ports 44 in the periphery of the drum, the rotation of the drum ensuring such flow. Although not so illustrated the chambers 1 may be equipped with cooling fins, preferably circumferential, to permit of maintaining a shell temperature below the ignition point of the charge and below the softening point of the shell, the former requirement being valid only with the explosion type of chamber.

The operation of the turbine shown in Figure 8 is as follows:—Starting must be accomplished by additional or extraneous means. Such means may take one of two main forms, i.e. means for supplying an explosive charge to the chamber without movement of the rotor, or means for driving the rotor to permit it to engender the required delivery pressure by centrifugal force. In some cases the first and in other cases the second means will be found most convenient.

Assuming that the initial supply of combustible mixture has been caused to enter the chamber 1, it is ignited therein and leaves each chamber in the form of a high velocity gas stream emerging in a generally tangential direction. The reaction impulse thus created, equal in amount to the momentum of the expelled gas is thus applied as a turning moment to the rotor, causing revolution thereof. By virtue of this revolution air is drawn in through the carburettor 32, becomes laden with gasolene vapour, and is delivered through the cavity 31, hollow shaft 29, hub 37 and radial pipes 38 to the bases of the respective chambers 1 under pressure. At the same time air is delivered under pressure by the scoops 39 to the bases of the chambers. Forcible delivery of the combustible gas and air is therefore accomplished without extraneous mechanism and indeed without motion save that of the rotor itself. Such delivery of the inlet gaseous fluid being provided, the chambers 1 operate automatically to increase the speed of the rotor, each increment of speed giving an additional increment of supply pressure with a consequent increment of rate of combustion and of reaction force. The turbine therefore possesses load-speed characteristics particularly desirable for many classes of work. Efficiency likewise increases with speed since heat losses from the chamber and nozzle become less, and the mechanical efficiency as expressed by the ratio of the relative velocity of exit of the gases to the absolute velocity of the chambers in the reverse direction becomes greater as the speed of rotation rises. The limit of this mechanical efficiency is fixed by structural considerations only. It appears practical to attain calculated mechanical efficiencies up to 40% by the use of a rotor of light weight and high strength attaining peripheral velocities of the order of 1000 feet per second. Net thermal efficiencies of the order of 10% should be attainable.

It is to be noted that the cooling effect on the chambers of the air circulating through the drum is likewise a function of the speed of rotation and of the same order as the increased rate of combustion, so that the entire cycle is self-balancing to a remarkable degree.

In the form of turbine illustrated in Figure 8 control is effected primarily by charge proportion varying. Regulation of the throttle 33 restricts or increases the flow of fuel gas to the turbine and thus effects such control. I am aware that in this form of turbine the inclination of the nozzle axis to the tangent line of the path of rotation results in a loss of power and efficiency. This defect may be reduced by reduction of the inclination or may be avoided entirely by other expedients and arrangements, some of which are hereafter described. The principles of operation and of design are, however, made clear and convenient of explanation by the example here chosen as illustrative of a simple embodiment of the invention.

In Figures 9 and 10 there is illustrated a turbine having two rotors mounted concentrically for rotation in opposite directions. The main rotor is journaled on a stationary hollow shaft 45 carried by a hollow base 46, the carburettor 32 being connected therewith as in the turbine previously described. The hub 47 of the main rotor carries a shaft 48 which in turn supports and drives an armature 49, being extended through the armature and journaled at its outer end in a stationary support 50. The secondary rotor has a tubular shaft 51 which is journaled on the shaft 48 and supports and drives a rotating electromagetic field 52. The rim of the main rotor is made up of two ring conduits 53 and 54 which are carried by and supplied through hollow radial spokes 55 and 56. The spokes 55 open into the cavity of the hub 47, thence to the carburettor 32, while the spokes 56 carry each an air inlet connection 57, the open ends of these connections lying in a common plane parallel with the plane of rotation. For controlling the air supply to these inlet connections a throttle ring 58 is journaled on the hub 47. A shifter yoke 59 the handle of which co-operates with a toothed quadrant 60, serves to advance and retract the throttle ring for regulating the air inlets 57.

The combustion chambers 1, which may be of either the continuous or the explosion type, are carried by the ring conduits 53 and 54, the respective air and gas supply pipes 61 serving both as conduits and structural supports for the bases of the chambers, while the outer ends of the chambers have separate supports 62. The chambers shown in Figure 9 have longitudinal cooling fins 63, while in Figure 10 these fins are omitted. The nozzles of the chambers used in Figures 9 and 10 lie in the plane of rotation but their axes are inclined slightly in the direction of the radii, in place of being tangential. Each nozzle is cut off on an arc of the path of rotation as shown at 64, and has a minimum working clearance with curved blades 65 carried by the rim of the secondary rotor. The usual shrouding of the blades 65 may be employed, this detail having been omitted for simplicity of illustration.

The operation of the primary rotor illustrated in Figures 9 and 10 will be apparent from the description. Rich mixture is supplied through the carburettor, hollow shaft 45, hub 47 and spokes 55 to the ring conduit 53, while air is supplied through the connections 57 and spokes 56 to the corresponding ring conduit 54. From these two conduits the fuel gas and air reach the bases of the combustion chambers 1. The gases emerging from the nozzles give the driving torque of the primary rotor, while the impulse of these same gases, to the extent of their absolute velocity, gives an additional driving torque of opposite sign to the blades 65 of the secondary rotor. The reverse curvature of these blades in combination with their movement in the direction of the gaseous impulse acts to absorb the kinetic energy of the exit gases by reducing their absolute velocity at the time they leave the system.

It is to be noted that the torques of the primary and secondary rotors, while of opposite sign are not necessarily balanced at the speeds chosen, such balance being obtainable only by experiment, and at times by loss of overall efficiency. On the other hand the resistance torques of the armature and rotating field are inherently balanced. This condition suggests the use of supplementary independent resistances to rotation for the primary and secondary rotors. Such resistances may be supplied in any ordinary way by treating the shafts 48—51 as power delivery shafts and connecting each to an independently adjustable load, for example through belt pulleys 66. Through this expedient the total resistance torque of the primary and secondary rotors may be varied to obtain the desired speed relationships. It is obvious that direct electrical loading against stationary fields of either rotor, or of both may be employed instead of the supplementary indirect loading through the pulleys 66, the latter having been illustrated solely for the sake of simplicity.

In Figure 11 there is illustrated a modified rotor construction showing one means by which both the fuel gas and the air may be supplied through the stationary hollow shaft. This is effected by using a double shaft made up of concentric tubes 67—68. The outer tube 67 serves as the bearing support for the rotor and as the gas supply conduit, while the inner tube 68 serves as the air supply conduit. An ordinary butterfly throttle 69 may thus be employed for regulation of the air supply.

In this design the hub of the rotor is journaled as usual on the outer tube 67 but carries on its outer face inner and outer caps 70—71. The space between the face of the rotor and the inner cap 70 forms a distributor for the gas entering through the annular passage between the tubes 67—68, communicating with alternate hollow spokes 72, thence with the right hand portion of a single ring conduit 73 forming the rim of the rotor. A web 74 divides this ring into separate conduits. The left hand portion or conduit communicates through alternate spokes 75 with the space between the inner and outer caps 70—71, into which space the air tube 68 discharges as shown. It will be obvious that the outer face of the rotor is continuous up to the diameter of the cap 71, the only openings being those into the spokes.

The ring conduit 73 may carry combustion chambers in the manner heretofore or hereafter shown, the purpose of this description being to illustrate only a possible variant of the rotor itself in which a single shaft supplies gas and air separately to a simple rotor in the form of a wheel with hollow spokes and rim.

In Figures 12 and 13 I have illustrated a rudimentary application of the principles of the present invention to the driving of a propeller or revolving wing, especially intended for aircraft, the turbine and propeller constituting a single structural unit which I call a turbo-propeller. The propeller or revolving wing, illustrated in plan view in Figure 12 and in transverse section in Figure 13 is of the usual form save that it is hollow and is mounted on a hollow stationary shaft, the propeller constituting itself the rotor of the turbine and being supplied with fuel gas through a stationary hollow shaft as in the construction heretofore described. The shell of the propeller is designated 76 and the shaft 77. Near the tip of each hollow blade is located one (or optionally any number) combustion chamber 1, which lies wholly within the body of the blade or wing. The axis of the chamber 1 is, in plan view tangential to the path of rotation. The base of the chamber lies toward the leading edge of the blade or wing, and the nozzle discharges tangentially at the trailing edge as shown in Figure 13. Air is supplied to the combustion chambers directly from the interior of the blades, entering through ports 78 near the hub, as shown. Fuel gas is separately supplied from the hollow shaft 77, thence through individual pipes 79 to each combustion chamber by centrifugal force in an obvious manner.

In Figures 14, 15 and 16 I have shown a four bladed screw propeller constituting the rotor of the turbine. The rim of this propeller is made up of ring conduits 80—81, supplied respectively with gas and air through the hollow blades, each of which is divided by a web 82 to form two separate radial passages. The combustion chambers 1 are constructed and mounted as in Figures 9 and 10, save for the circumstances that each nozzle is bent to discharge tangentially as shown at 83 in Figure 14.

A continuous cowling may be used to enclose the ring of combustion chambers in order to reduce the air resistance set up by the rapid motion of these parts. Or the spaces between chambers may be filled with small fairing surfaces. These expedients for reducing air resistance are not illustrated, since the principles thereof are too well understood to require explanation.

In Figures 17, 18 and 19 there is shown a modified turbine construction especially adapted to the driving of propellers or revolving wings having high peripheral speeds with resultant great centrifugal forces acting upon masses remote from the center. The purpose of this design is to attain further simplicity of construction and particularly to permit of maximum peripheral velocities and resultant high mechanical efficiencies of the turbine without meeting unsolvable structural problems.

For this purpose I may employ a central rotor construction similar to that shown in Figure 11, that is to say the central portion of the rotor is essentially a simple wheel designated 84 the rim 85 of which may either be divided for separate supply of gas and air or may consist of a single passage through which the complete mixture ready for combustion is delivered. For the sake of simplicity I have chosen the latter alternative in illustrating the design of Figures 17 to 19.

Mounted in and carried by the rim 85 are four symmetrically disposed pairs of radial combustion chambers 1. The base of each chamber lies within the rim, and as shown in Figure 18 has spring loaded poppet type intake valves 86 arranged for tangential reciprocation carried in the side walls of the base. The bodies of the chambers lie outside of the rim 85, and may have circumferential cooling fins to reduce the shell temperature. To the outer ends of the combustion chambers are affixed propeller blades 87, which may be hollow and may serve as carriers and fairing for the nozzles of the combustion chambers. These nozzles, designated 88, extend radially outward along the blades and terminate in bent extremities 89 which discharge the exit gas tangentially.

Optionally, the propeller and the turbine may constitute semi-independent structural units, the one superimposed on the other. In that case the nozzle pipes 88 may form the leading and trailing edges, or be recessed into and secured to a solid blade as shown at 88a in Figure 19a. Where high temperatures are to be applied to structural elements carrying material loads, the use of the alloy of steel heretofore mentioned is advantageous. Thus the propeller blade and nozzles of this modification may be constructed of this alloy.

Among the peculiar advantages which the turbine construction of the present invention presents when employed as a means for driving propellers or revolving wings for aircraft the following may be mentioned. The absence of any reaction torque on the shaft is of great advantage from the standpoint of aerodynamic design in the case of airplanes. In the case of helicopters the absence of reaction torque makes possible the use of a single revolving wing, and instead of leaving orientation as a problem of balance between oppositely reacting lifting surfaces it renders possible a power control of orientation independently of aerodynamic consideration by the direct application of a brake to the rotor in a manner hereafter illustrated. In all cases the use of the turbine for propeller drive results in applying the driving torque at or near the tip of the blade or wing instead of through the hub, and with symmetrical designs the latter has no unbalanced load save the thrust load. This materially simplifies the problems of propeller design and effects a saving in weight. It is to be noted from the standpoint of weight that the propeller itself and its shaft replace structurally the shaft and rotor of the turbine, so that the same necessary structural elements become common to the driving and driven members, the whole constituting a unitary device for generating and absorbing mechanical energy by action and reaction of gases. The cooling of the combustion chamber shell is aided by utilizing both the rotational velocity and the translational velocity of the aircraft, as necessarily results from the mere exposure of the chambers or portions thereof to the atmosphere.

The load-speed characteristics of the turbine are also of the type best suited to propeller drive, maximum driving torque coming with maximum load, and starting being accomplished under conditions of no load without the use of a clutch. The turbine of the present invention is, therefore, in many important ways of peculiar value when driving air propellers or revolving wings for aircraft, either as a separate power unit or as a unitary turbo-propeller.

In Figure 20 I have illustrated a form of muffler or silencer which may be employed in connection with my turbine. This consists of concentric pipes 89—90 into which the nozzles 91 of the explosion chambers 1 lead. Each pipe is perforated with large numbers of holes the aggregate area of which far exceeds that of the turbine nozzles. In perforating these holes by a punching operation there are left attached lips 92 which are curved outwardly and tangentially to deliver the exit gases finally in a tangential direction at a velocity so low as to cause no sound. Where chambers of the explosion type are employed the muffler acts in the same manner to reduce the noise of the explosion.

In Figure 21 I have shown a conventional bi-plane the propeller of which is driven by a turbo-propeller, as has been heretofore described. The shaft 93 on which the propeller rotates is led through a universal joint or swivel support 94 in the nose of the fuselage and carried back to a point convenient to the control seat. In this position it forms a separate useful control device, permitting the line of thrust or drag to be altered in any direction by suitable adjustment of the projecting end of the stationary shaft 93. Locking means not shown may obviously be employed for holding the shaft in any adjusted position. This design, which is theoretically applicable but structurally very difficult in the case of propellers driven by known types of prime movers, here presents no important complication and is of service in improving the range of performance of conventional aircraft.

In Figures 22 and 23 I have illustrated diagrammatically a simple helicopter consisting of a nacelle 95 which may carry the ordinary control surfaces used on the tails of airplanes. The stationary hollow shaft 96 which supports and supplies the turbo-propeller 97, is carried in a universal joint or swivel 98 in the top of the nacelle and applies at this point the thrust of the propeller. The hub of the latter is brought down over the shaft in the form of a sleeve 99 terminating in a spherical surface 100 concentric with that of the swivel support. A brake shoe 101 actuated by a control arm 102 may be engaged with the surface 100 to cause a torque drag on the nacelle, which will serve to orient the same independently of the control surfaces, as for example while making a substantially vertical ascent or descent. For angular adjustment of the shaft 96 with reference to the nacelle I have shown a spherical friction surface 103 on the lower end of the shaft. With this is engaged a smaller spherical surface 104 carried on a stationary support 105 and oscillatable in any direction by a handle 106. The carburettor 107 is connected with the shaft 96 by a flexible pipe 108 in order to permit the adjustment of the shaft. Such adjustment serves as the means for controlling stability and translational movement of the helicopter through displacement of the centre of gravity with reference to the line of thrust. Like the construction shown in Figure 21, the swiveled arrangement of the shaft in the body of the machine is theoretically possible with a helicopter driven in the usual way but it is in fact so difficult of accomplishment as to have been unused in practice. The peculiarities of the present turbo-propeller unit permit a simple and practically useful embodiment of this principle.

In the foregoing specification and in the drawings annexed I have described and shown various embodiments of my invention but I have not attempted to set forth in any detail the numberless combinations of the various elements and forms thereof which are possible.

In the appended claims it is my intention to claim all that is novel in these elements and in their manifold combinations and modifications, as broadly as is permissible in view of the prior art.

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. An explosion reaction turbine comprising a rotor adapted to operate at a peripheral velocity of at least about one thousand feet per second, an explosion type combustion chamber carried by the rotor, means for repeatedly and with extreme rapidity supplying charges of explosive gases to said chamber, means for igniting the gases only when the chamber is substantially filled, means for confining the ignited gases whereby their heat energy is converted into pressure energy, an expansion tube of relatively small diameter opening from the chamber through which the confined high pressure gases escape at a relatively mean velocity of discharge of the order of but greater than the peripheral speed of the rotor, whereby the pressure energy of the charge is converted into kinetic energy of the escaping gas stream, said expansion tube being carried to a point adjacent to the

periphery of the rotor, and there discharging the gases tangentially in a direction opposite to that of rotation whereby the absolute velocity and heat energy content of the released explosion gases is greatly reduced at the expense of the useful work performed in the rotor.

2. A turbine constructed and operating in accordance with preceding claiming clause 1 and in which the gaseous charge is supplied by the high centrifugal force engendered of the high peripheral velocity of the rotor.

3. A turbine constructed and operating in accordance with preceding claiming clauses 1 or 2, and in which the chamber is mounted on the rotor at a point well within its periphery, whereby the rotor structure is relieved of the high centrifugal strains which would result from carrying the chamber at the periphery.

4. The several forms of my improved turbine constructed substantially as hereinbefore described with reference to the accompanying drawings, for the purposes specified.

Dated this 30th day of July, 1930.

D. YOUNG & Co.,
11 & 12, Southampton Buildings,
London W.C. 2,
Agents for the Applicant.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1932.

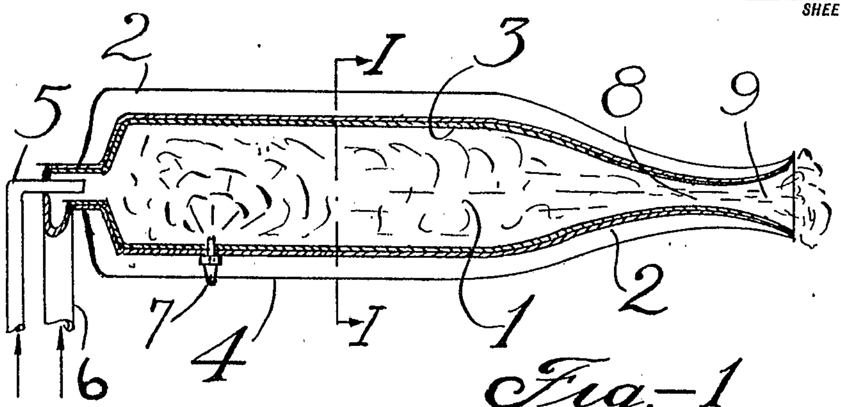


Fig.-1

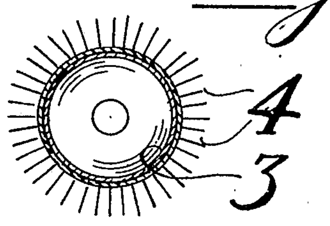


Fig.-2

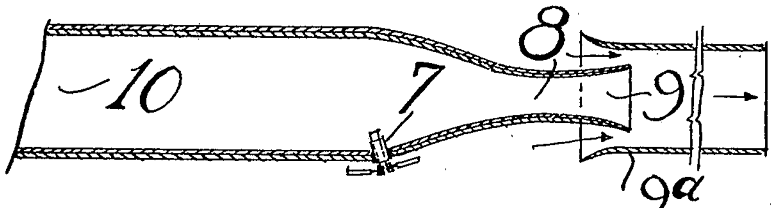
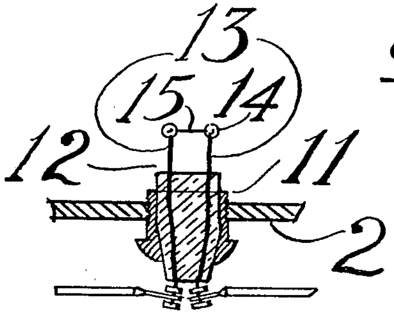


Fig.-3



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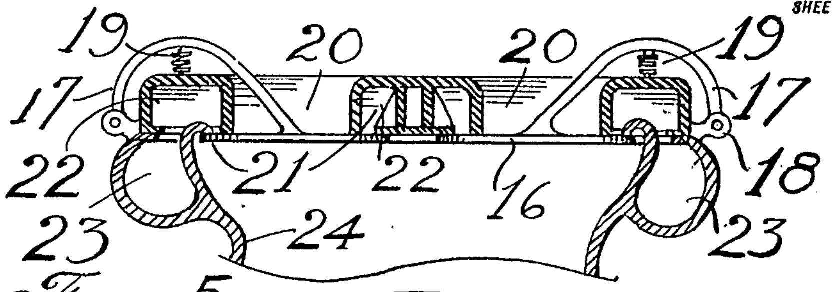

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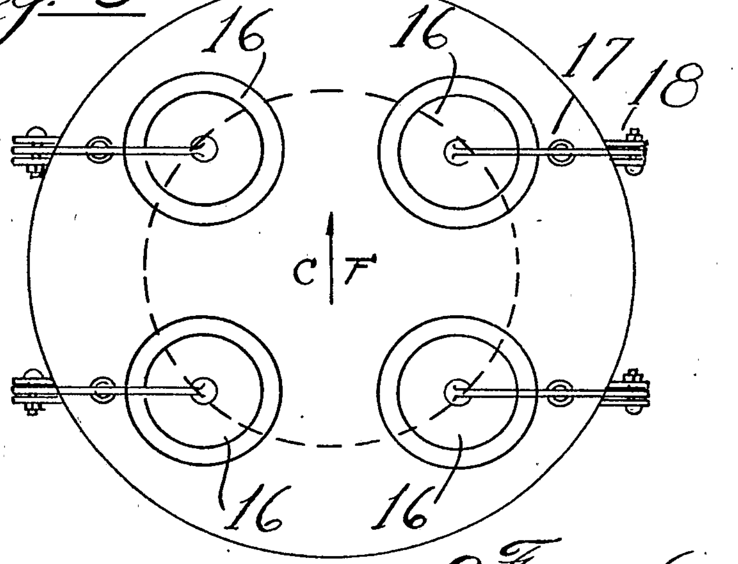

Fig.-6

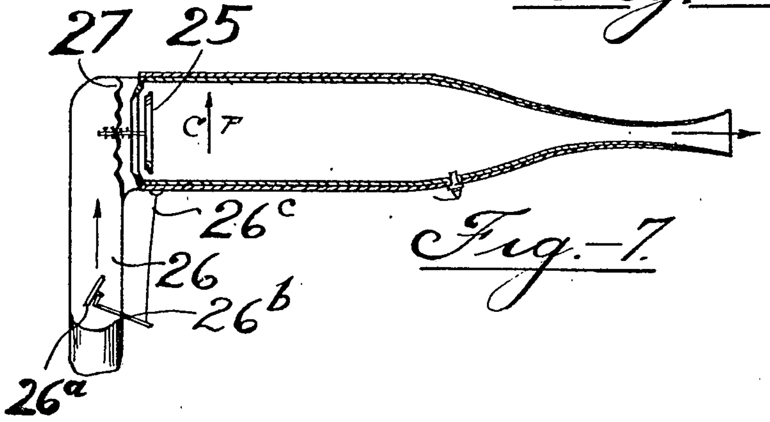

Fig.-7.

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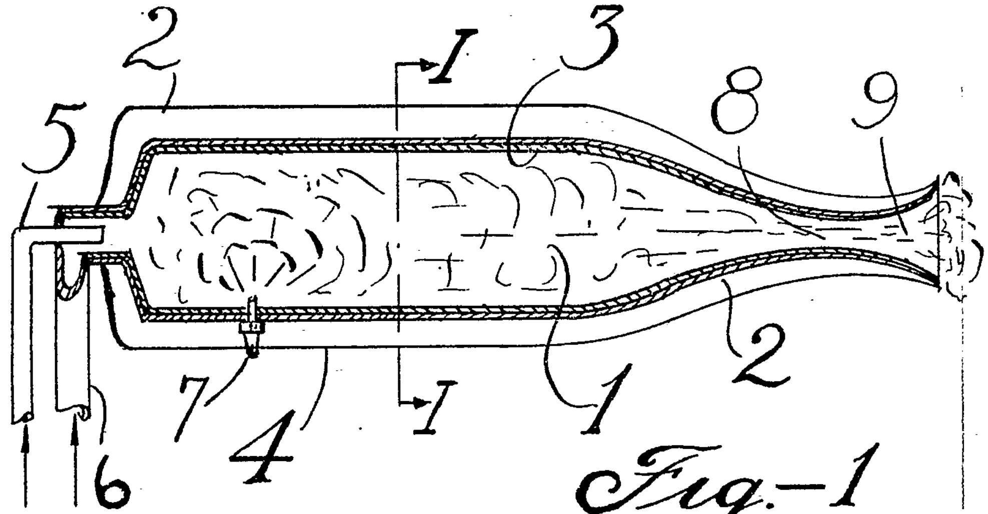
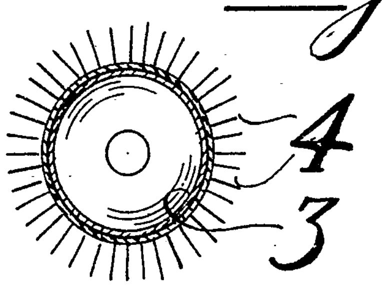


Fig.-1



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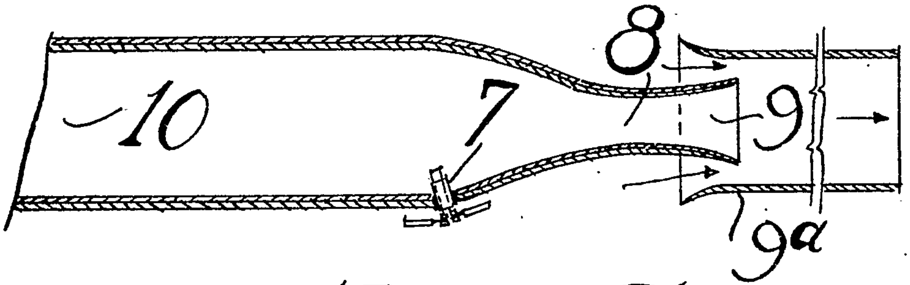
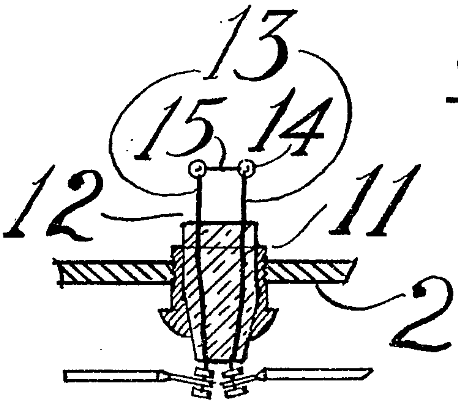


Fig.-3



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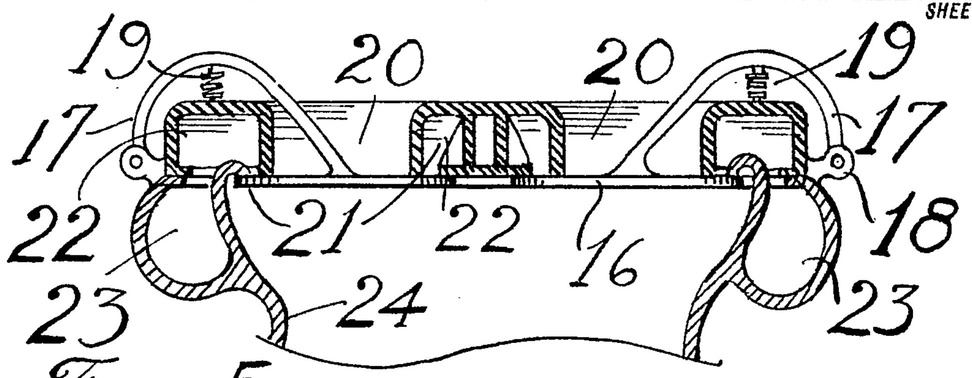

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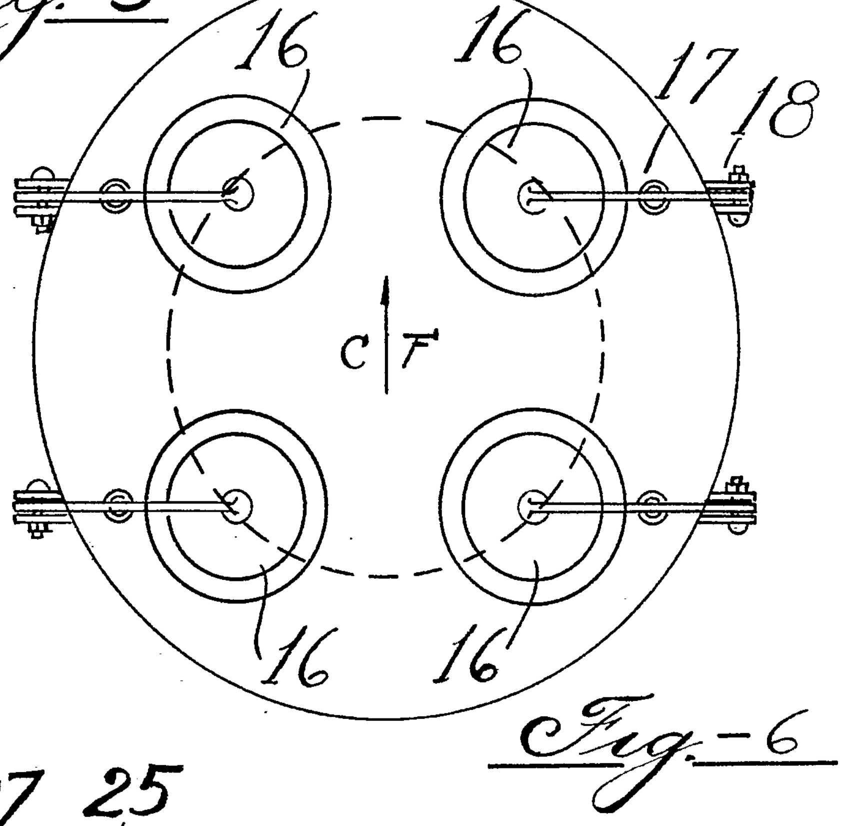

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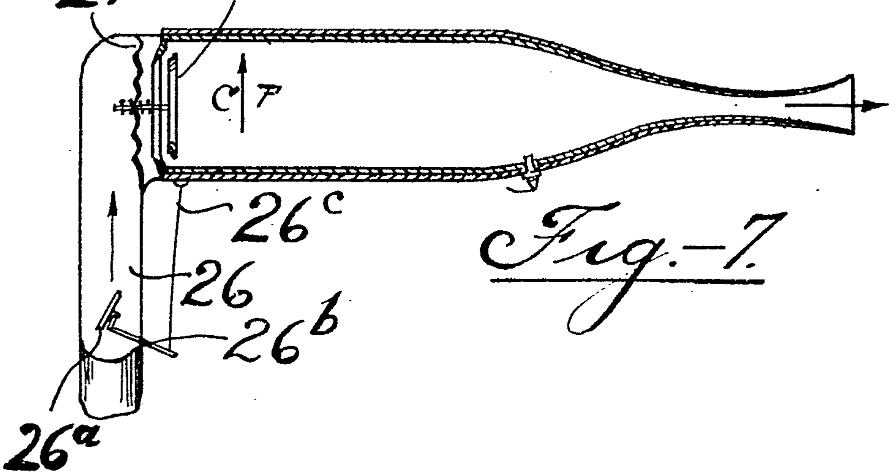

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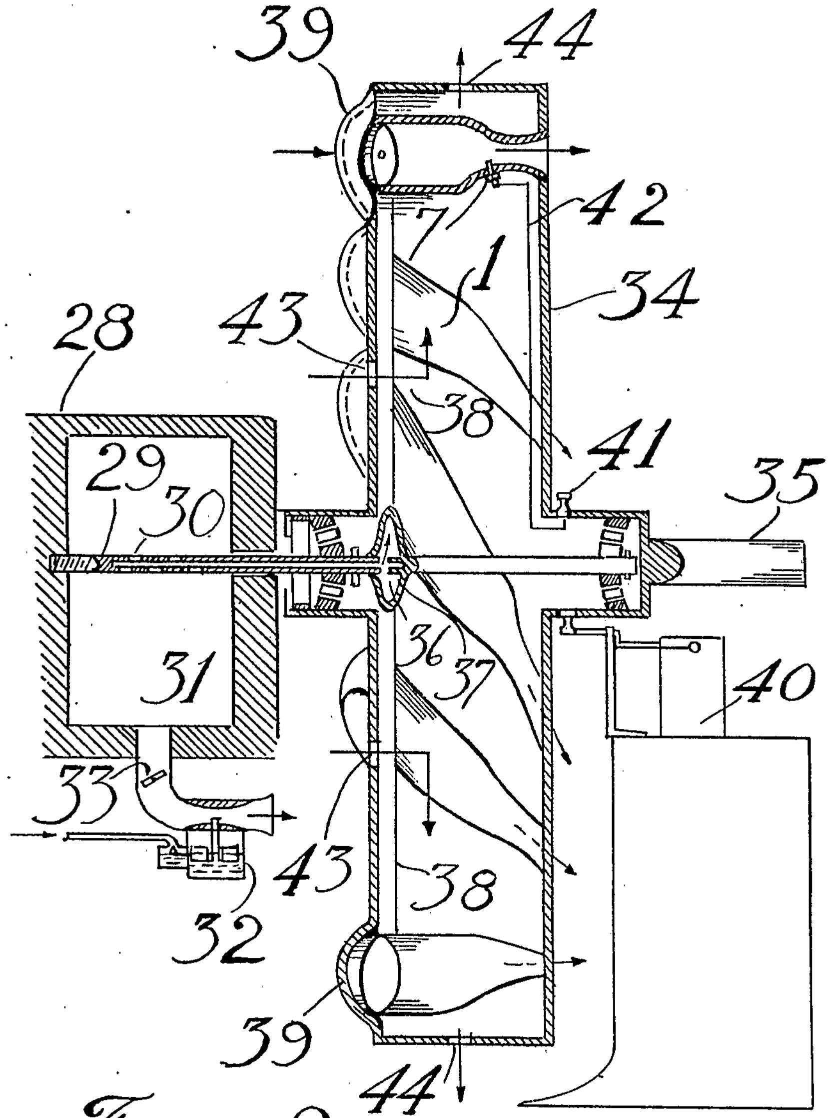

Fig. 8

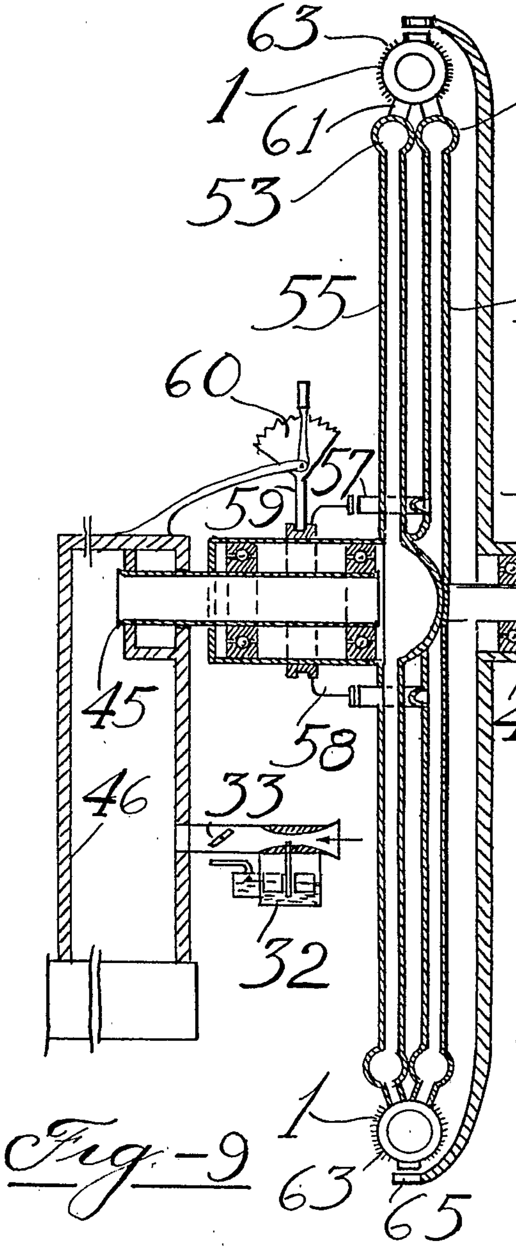

Fig. 9

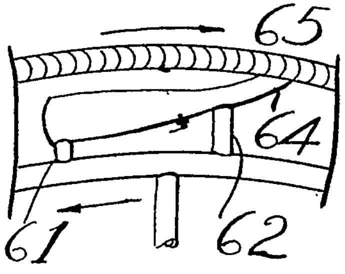

Fig. 10

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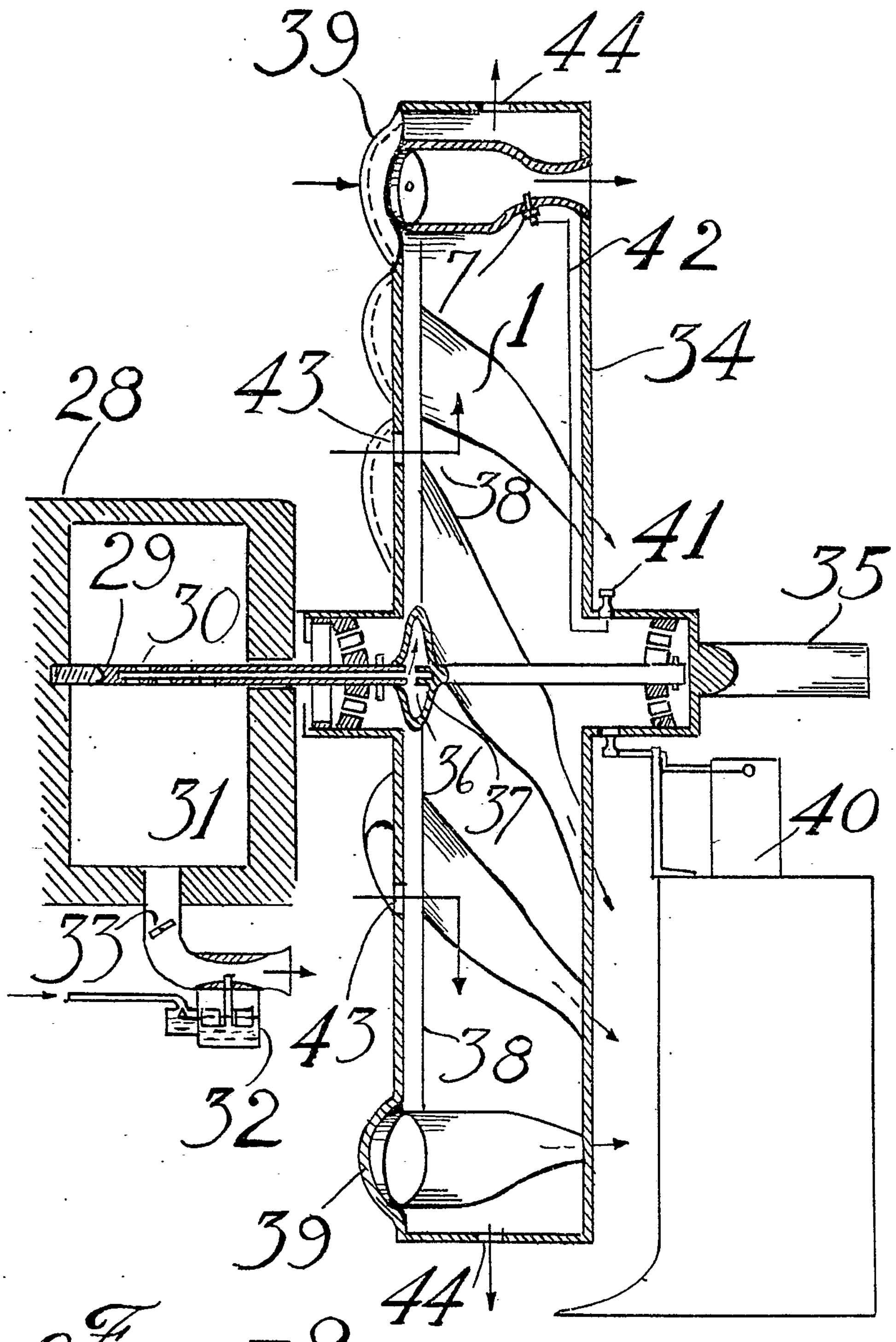

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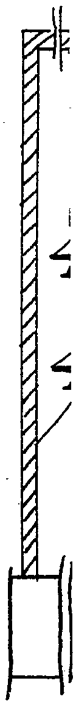

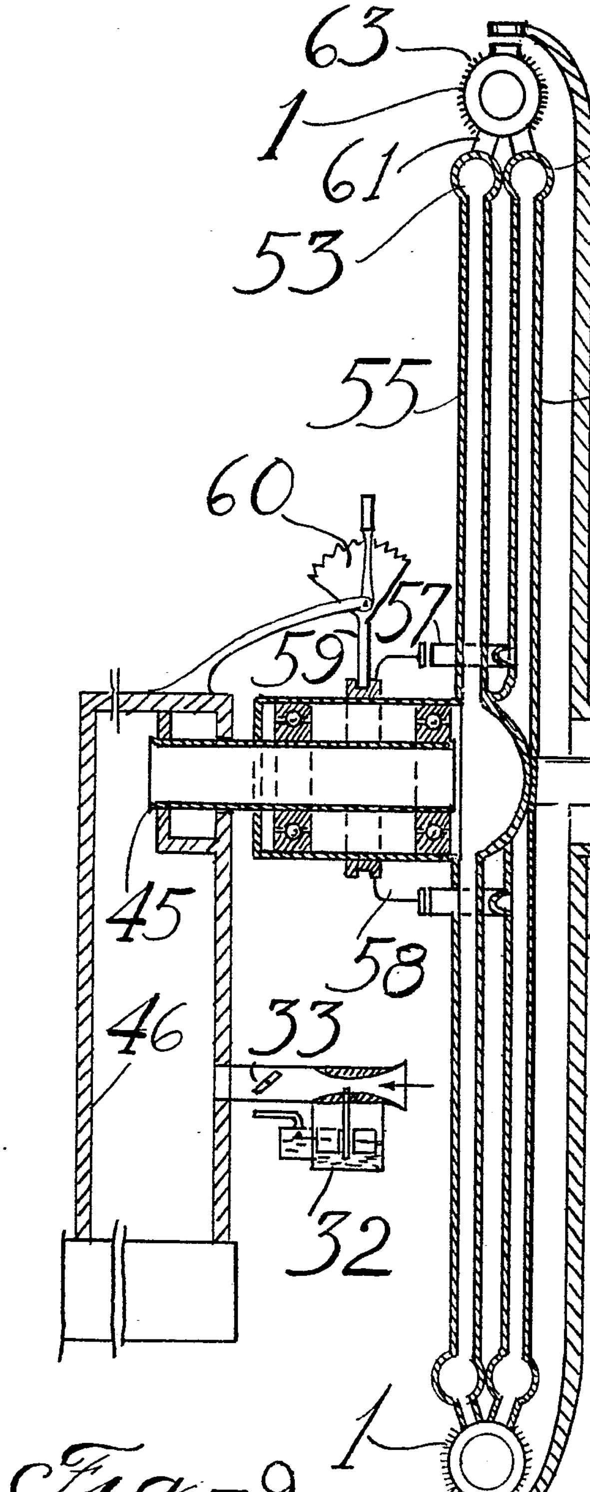

Fig. 9

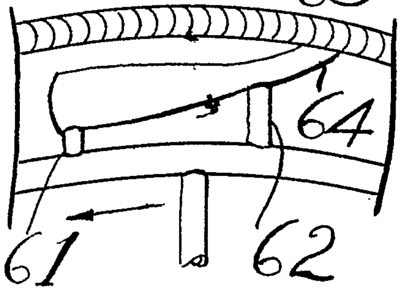

Fig. 10

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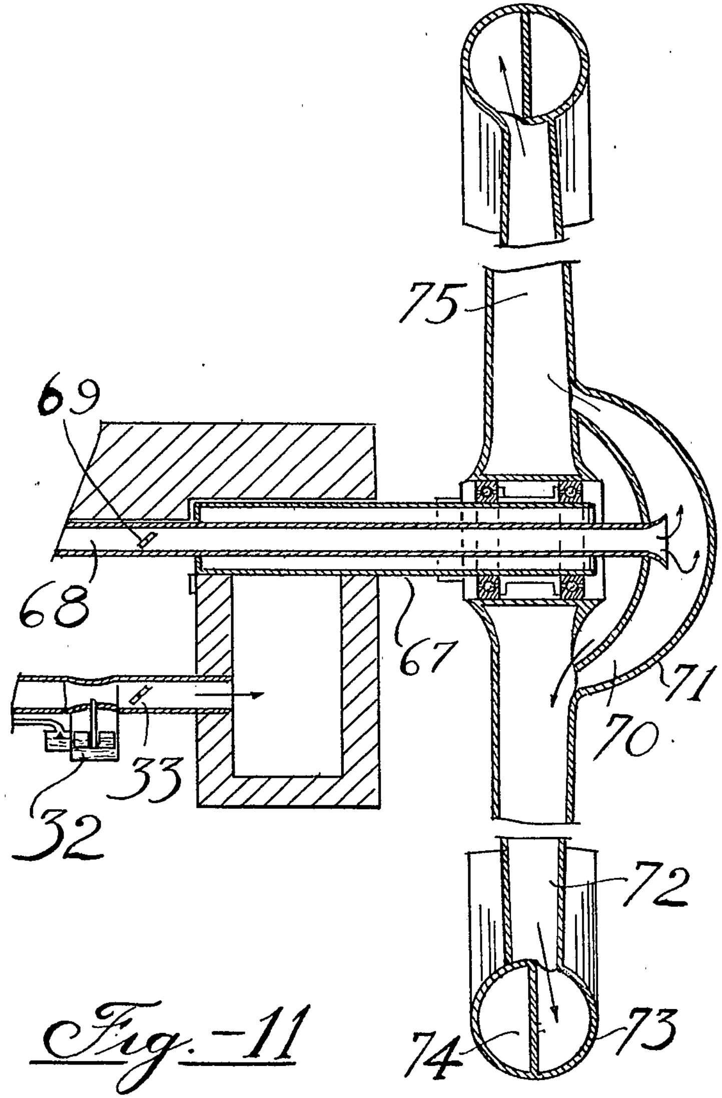
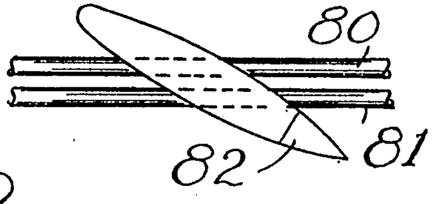


Fig.-11

Fig.-15



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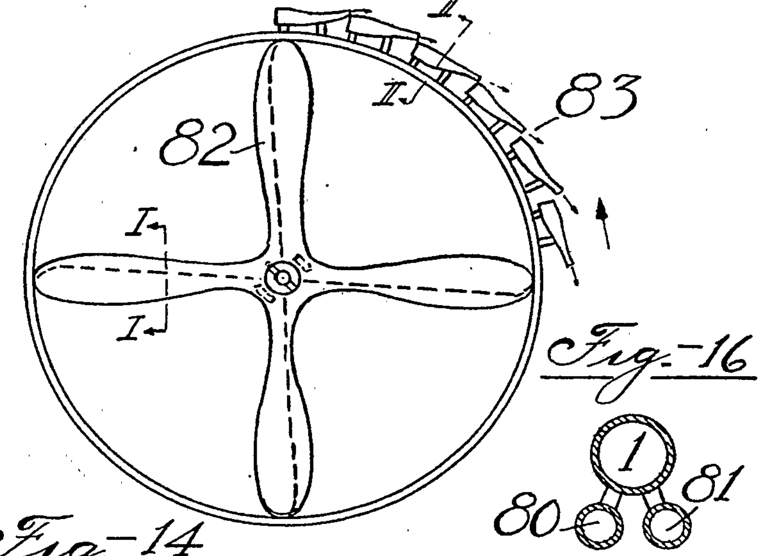
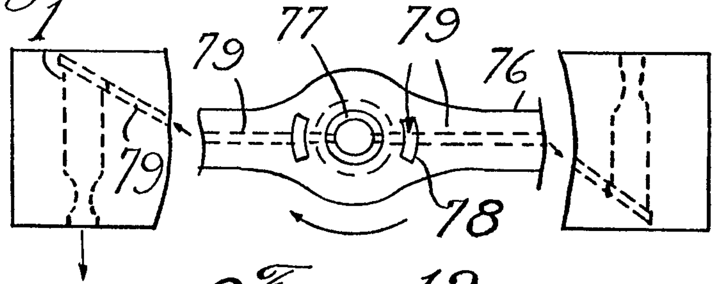


Fig.-16

Fig.-14



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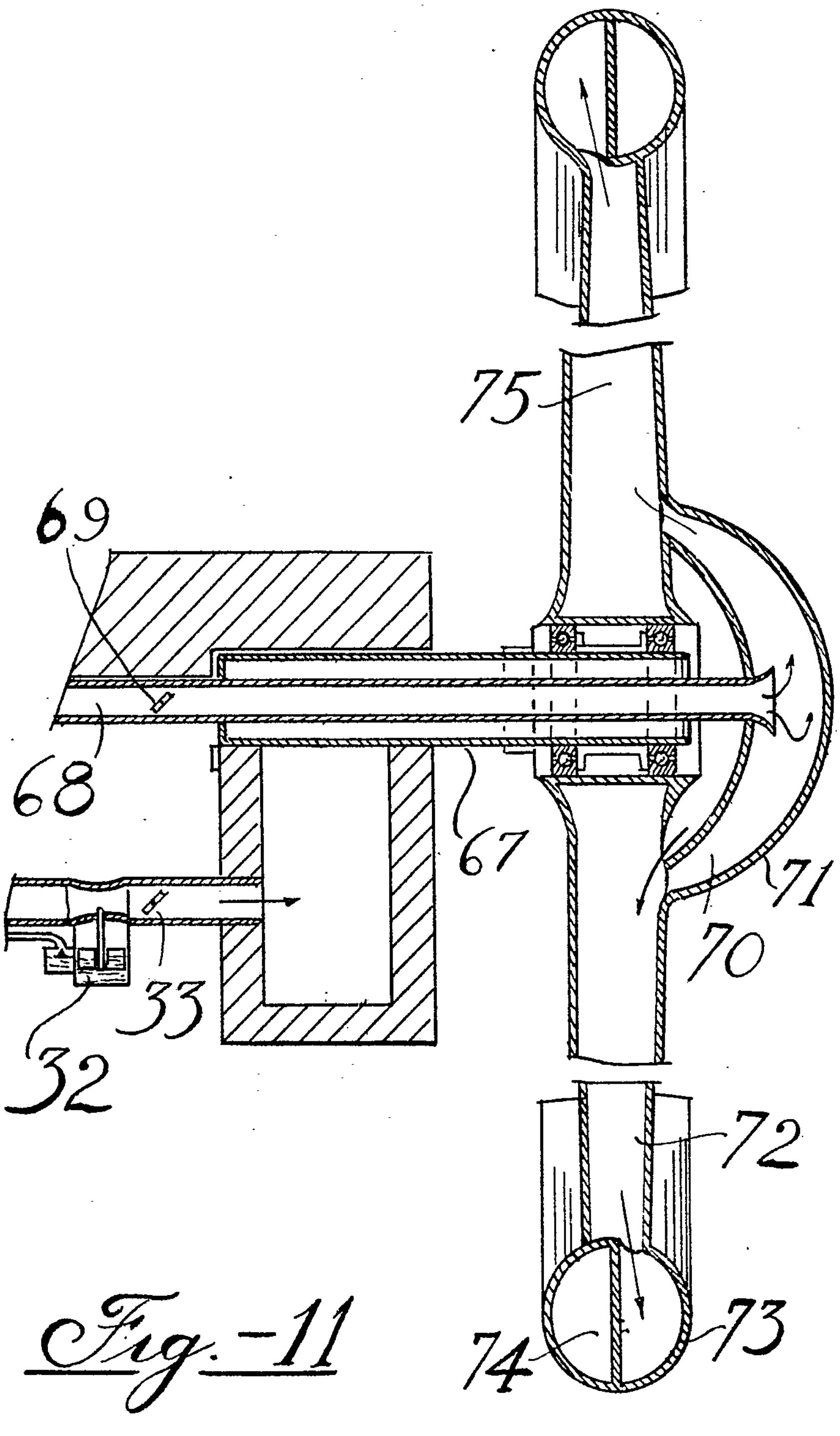
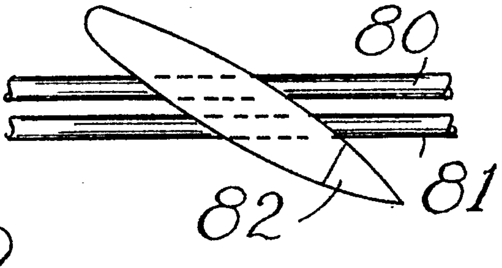
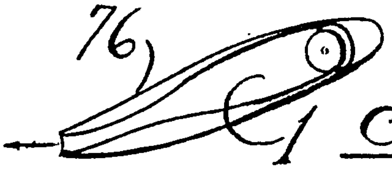


Fig.-11

Fig.-15





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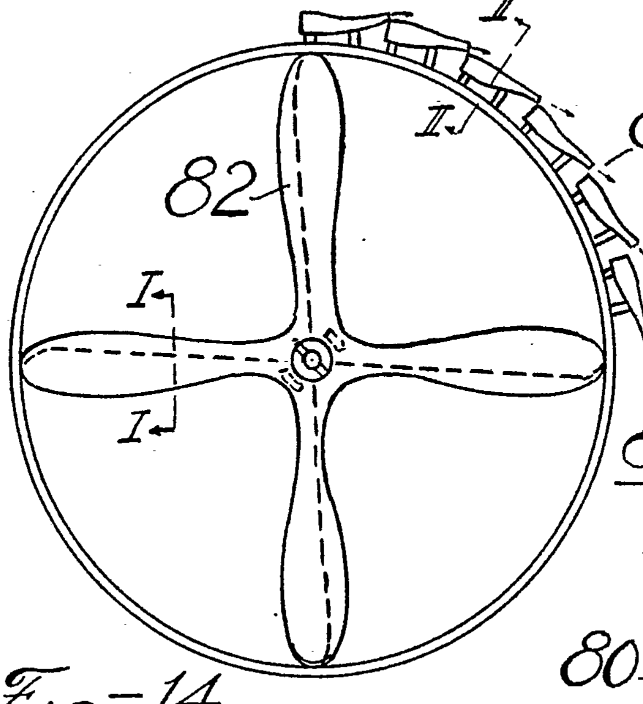

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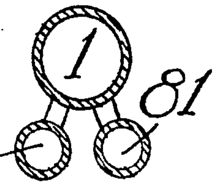

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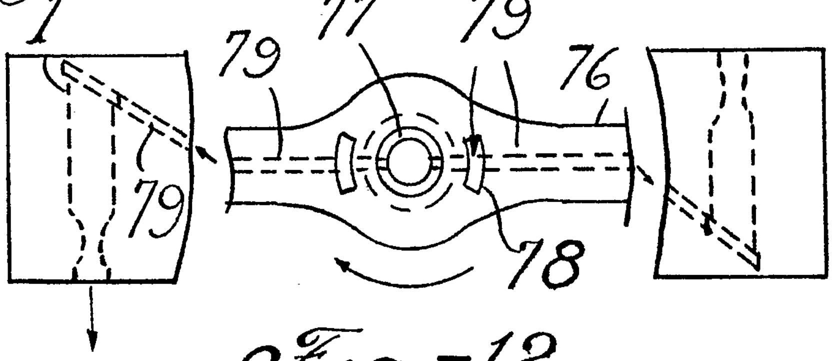

Fig.-12

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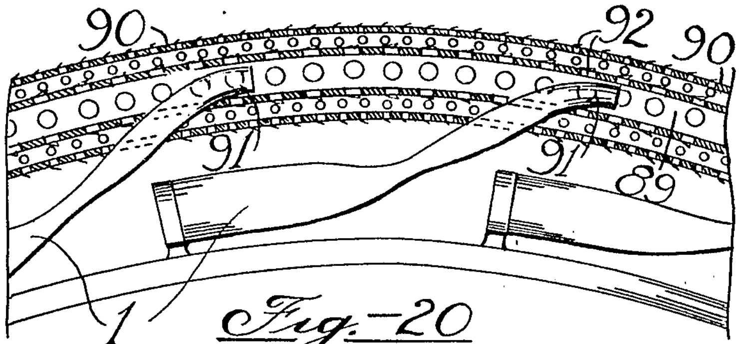
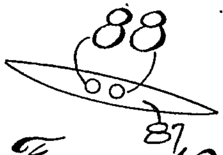


Fig.-20



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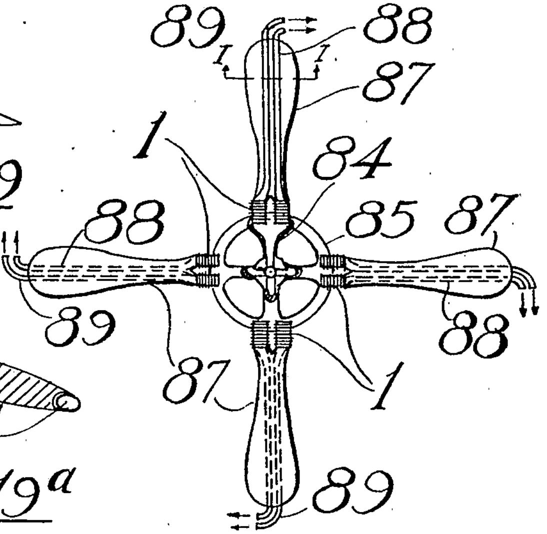


Fig.-17

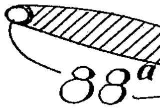
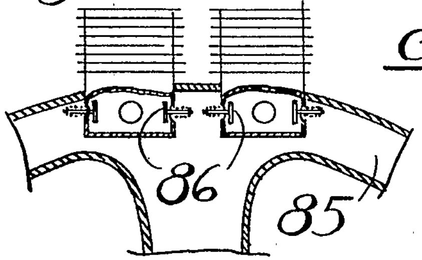


Fig.-19a



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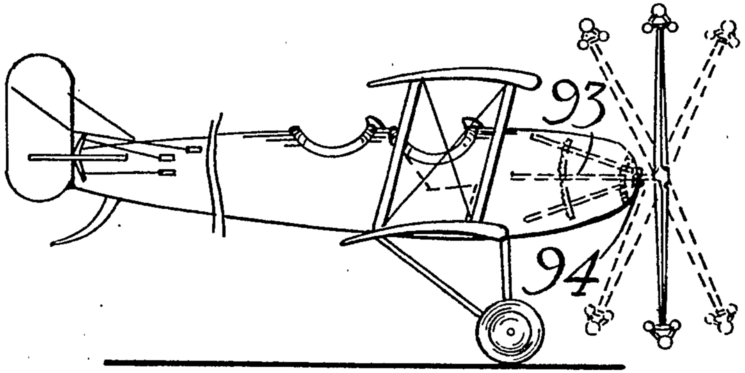

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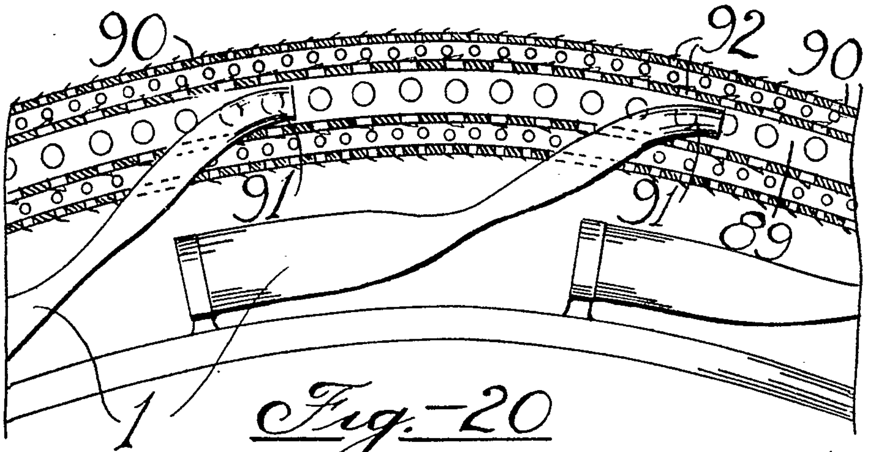

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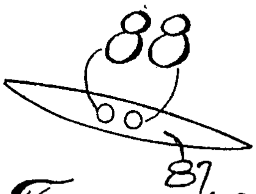

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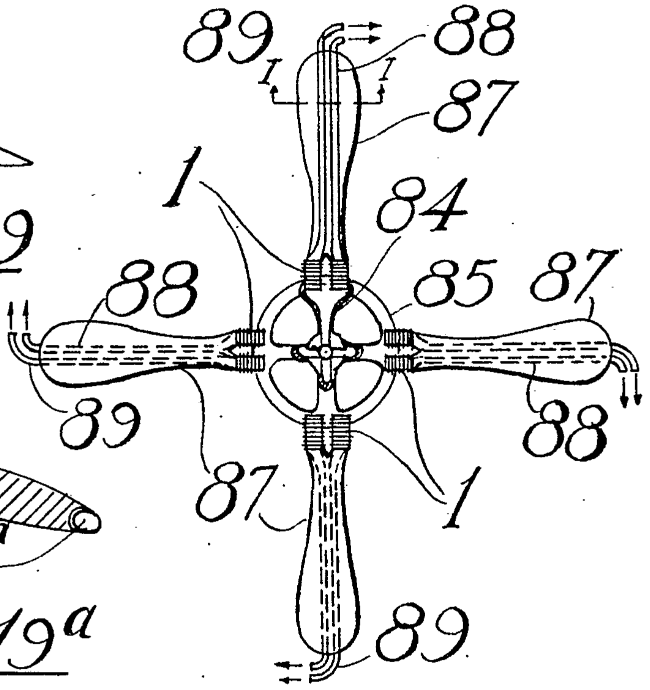

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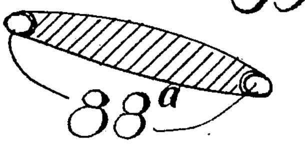
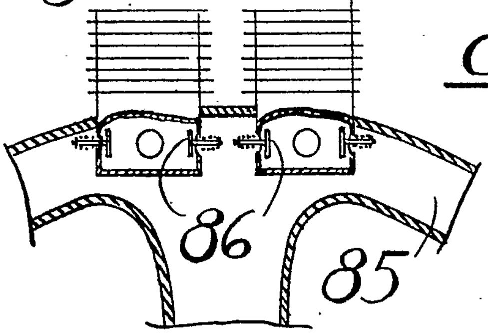


Fig.-19a



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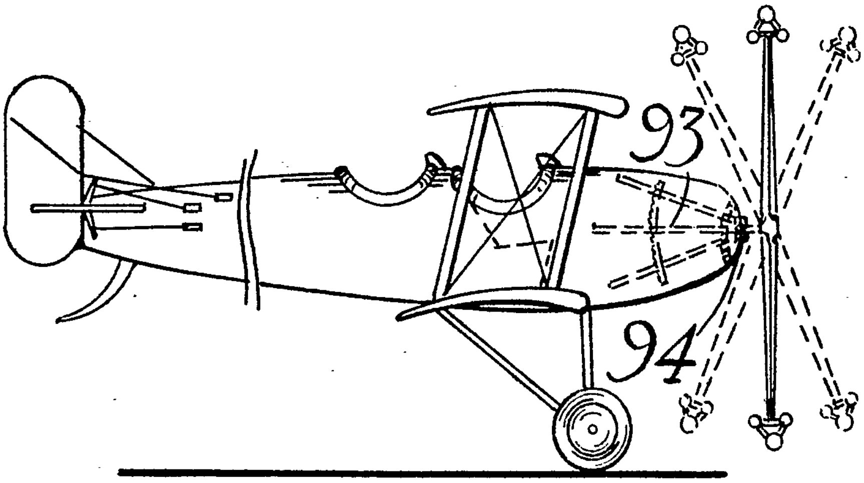

Fig. 21

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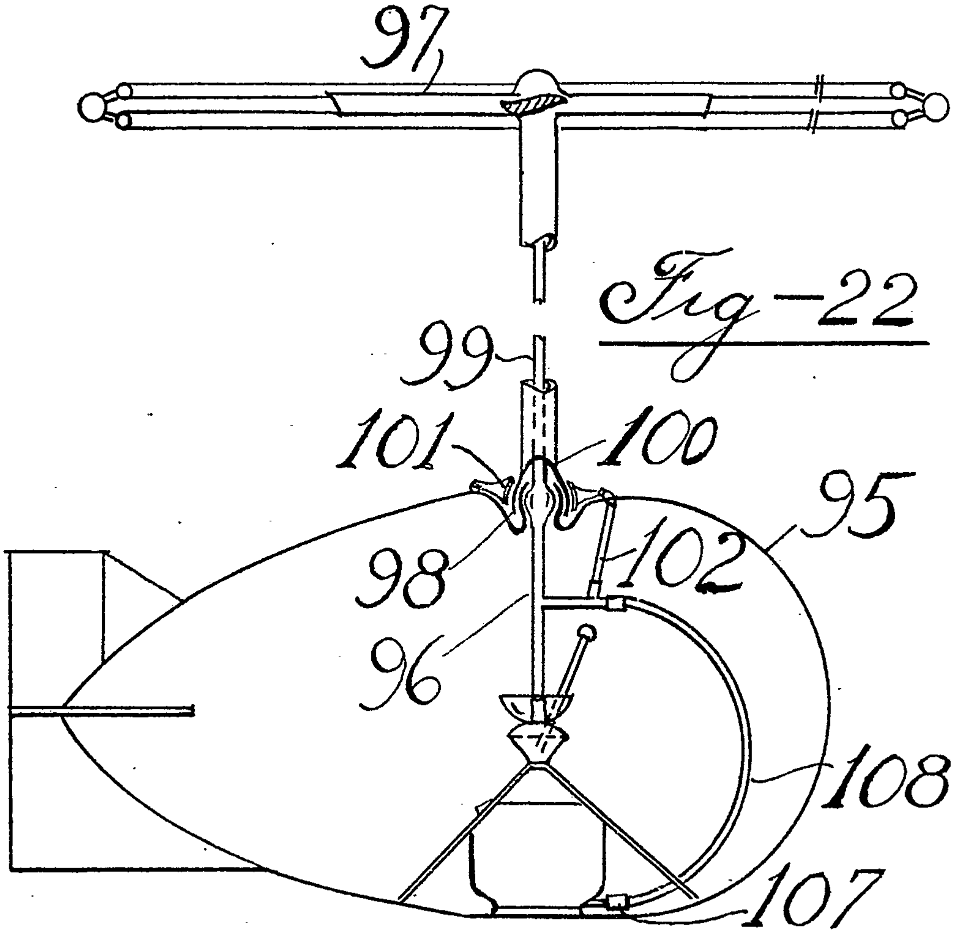

Fig-22

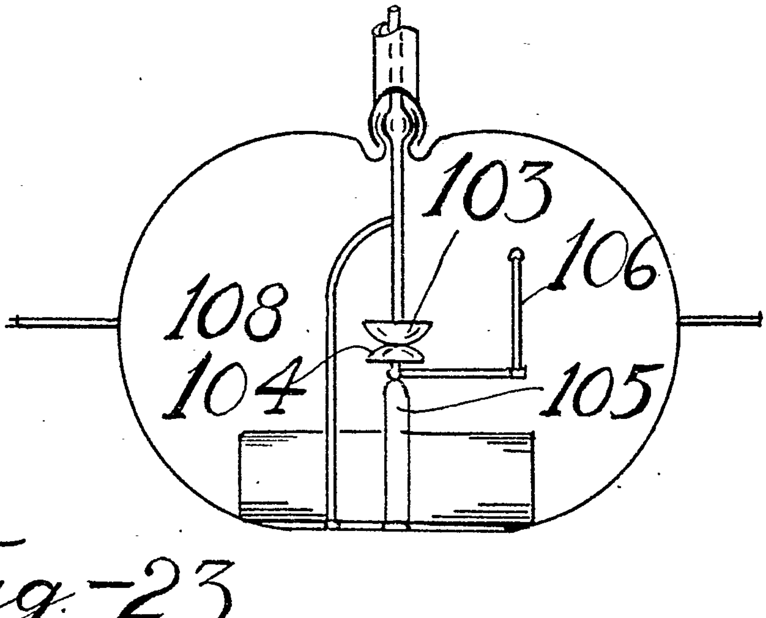

Fig-23

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