July 18, 1961 A. M. CADDELL 2,992,684

IMPULSE AND REACTIVE TIP-DRIVEN ROTOR

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FIG. 1

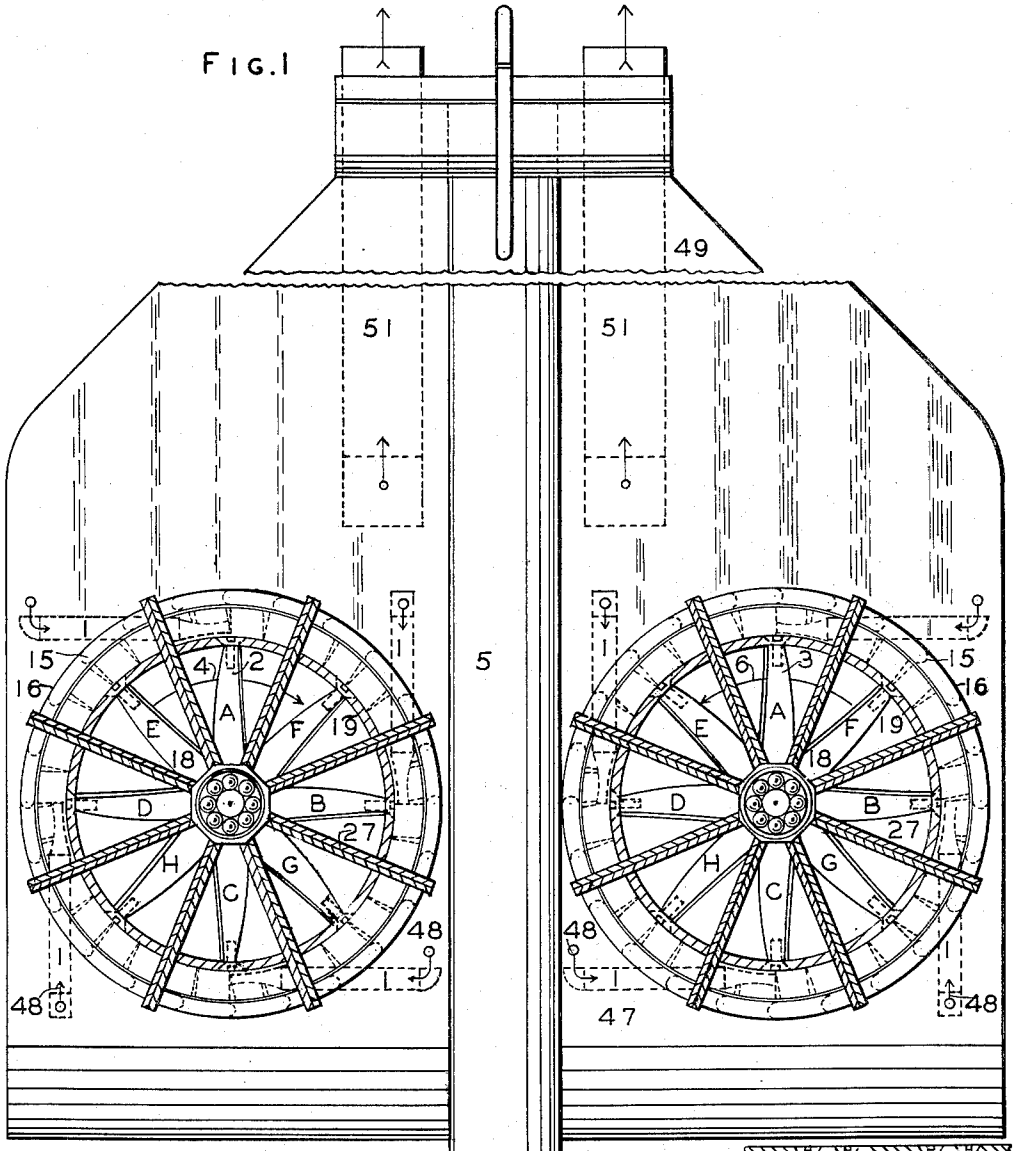


FIG. 2

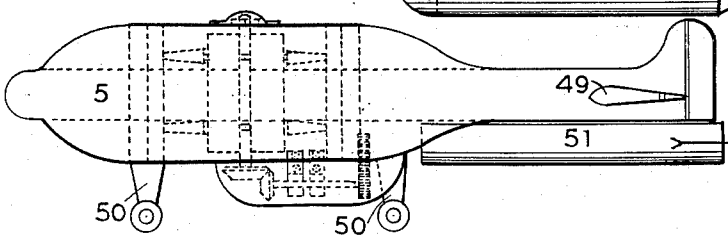
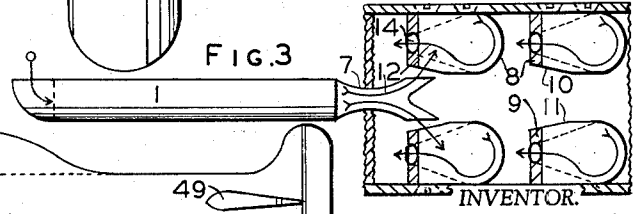


FIG. 3



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FIG. 4

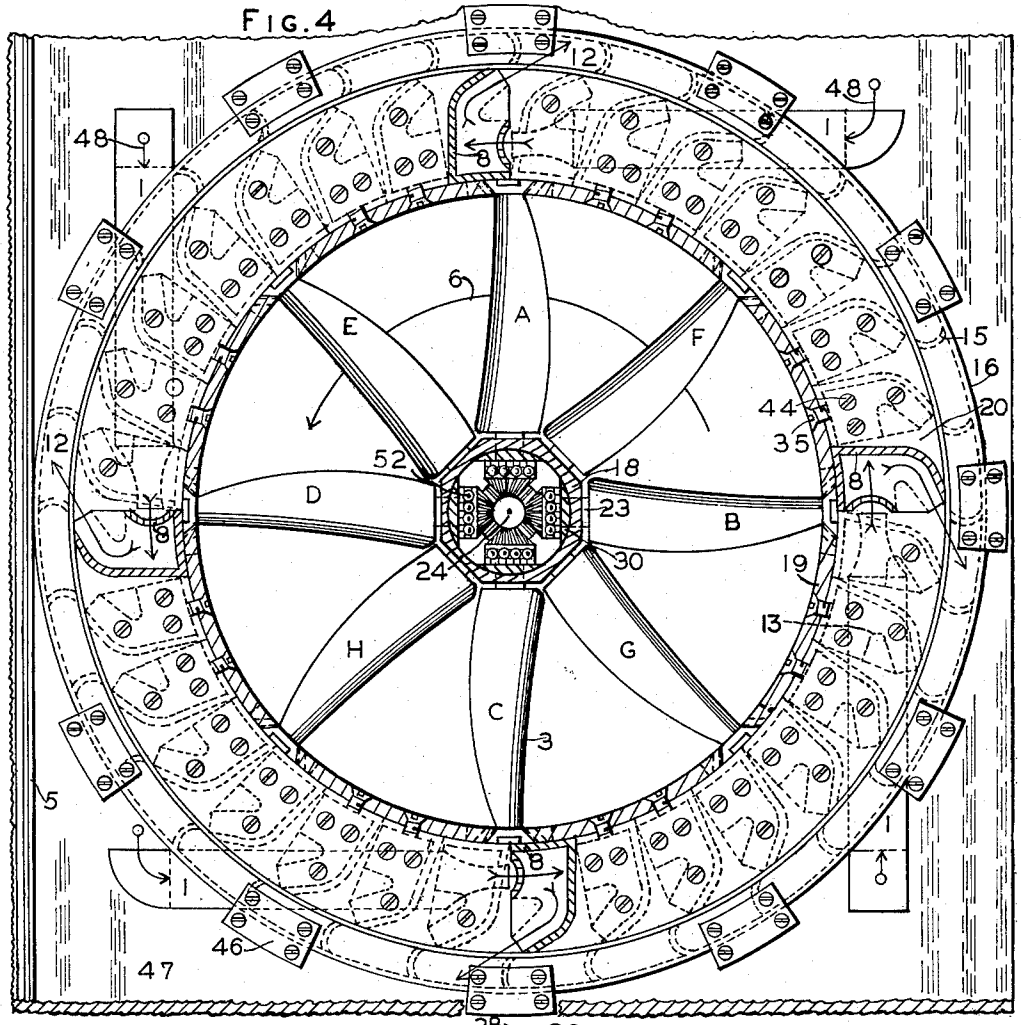


FIG. 5

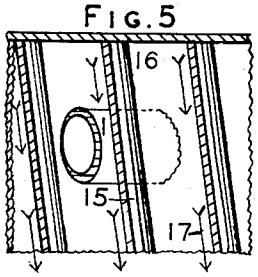


FIG. 6

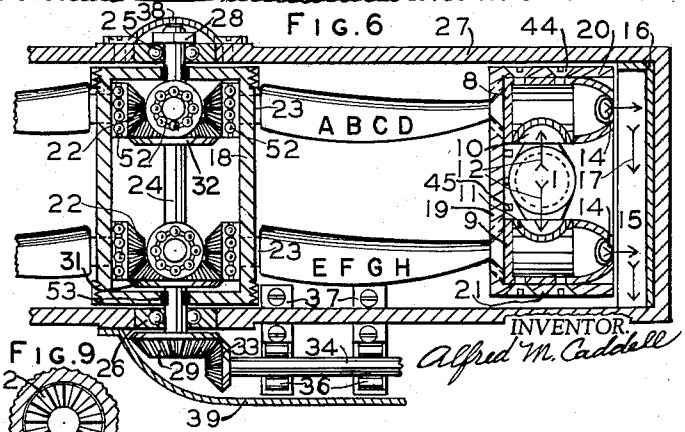


FIG. 7

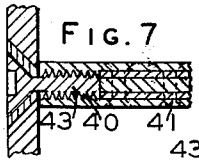


FIG. 8

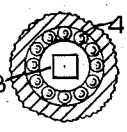


FIG. 9

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IMPULSE AND REACTIVE TIP-DRIVEN ROTOR

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9 Claims. (Cl. 170—135.71)

This invention offers a new type of turbine drive that due to operating at maximum leverage radius delivers maximum torque per pound of motive fluid pressure; which torque when applied to rotors comprising propeller assemblies is most appropriate for attaining vertical lift in aircraft.

Specifically, a single passage of high-temperature, high-pressure motive fluid into, through and out of turbine buckets mounted peripherally on the rotors accomplishes powerful impulse drive and simultaneously powerful reactive drive of the rotors, resulting in large masses of air being driven downward; and after doing this work the thrust energy in the fluid is further converted reactively into lift by it, too, being discharged downwardly to atmosphere. Such application of energy at the periphery of the rotor, or rotors, means that a maximum amount of work can be accomplished with a minimum amount of energy.

Excepting those rotated by tip reaction, propellers have always been driven via shaft drive. However, experiments conducted by this applicant have demonstrated that for vertical lift purposes far more productive results can be achieved by focussing high-pressure fluid against buckets of a turbine construction movably mounted on the tips of propeller blades; and, after the build-up of centrifugal force in the fluid in the interior of the buckets, discharging it through converging orifices at the buckets' extremities in a direction opposite to that of the propellers' rotation.

In the above-mentioned experiments, four blowers were spaced equally around a supporting body construction to discharge their air output against a turbine construction peripherally mounted on the tips of a four-bladed propeller, substantially as described herein.

In the present invention, four small pure jet engines take the place of the blowers, their tail pipes occupying a space provided between a top and a bottom bank of buckets. These engines are likewise spaced at equal distances in the body of the craft and surround a circular stator assembly which, in turn, surrounds each of the rotors. Four applications of high-potent energy per rotor are thus being constantly directed against the buckets and reactively discharged therefrom to assist in the rotors' rotation.

The turbine construction herein employed is comprised of a true-circle wall having a top and a bottom flange that extends right angularly outward to form a U-shaped channel which is movably mounted on the tips of propeller blades. In the preferred embodiment of this invention, as illustrated herewith, there are two rotors, one functioning on each side of a fuselage. Each rotor is comprised of two propeller assemblies, each assembly having four blades which are separated depthwise and alternately spaced from each other to avoid thrust interference therebetween. Eight points of contact between the propeller hub and the U-channel of each rotor are thus established, the blades of the top assembly engaging the true-circle wall at the 0, the 90, 180 and 270 degree locations thereof while those of the bottom assembly engage the wall at the 45, 135, 225 and 315 degree locations.

The turbine buckets per se are secured to the outer surface of the true-circle wall of the U-channel and to the bottom of the top flange thereof, while another bank of buckets is similarly secured to said wall but to the top of the bottom flange. They are designed to receive direct impingement of the fluid in their inner ends, throw it centrifugally within their confines and discharge it through a converging orifice at their radial extremities in a direction opposite to that of the rotors' rotation, thus setting up the aforesaid reactive drive.

A single integrated rotor is thus comprised of an elongated propeller hub, two banks of assemblies, each bank having four blades, a U-channel formation and the turbine buckets, whereas the stationary, co-functioning parts of the combination are comprised of equi-spaced, small-size pure jet gas turbine engines that supply the motive fluid, also an encompassing framework for supporting said rotor and a stator ring wall having curved blades positioned on the inner surface thereof to direct the motive fluid downwardly to atmosphere after it has done its impulse drive against and reactive drive work from the turbine buckets.

To neutralize torque developed by each of the rotors, one is mounted to turn clockwise and the other counter-clockwise.

In the employment of shaft-drive propellers, vibrations originating in the engine are transmitted to the propeller tips, thus causing dangerous flutter and, at times, violent out-of-track rotation which sets up loud whip-cracking noises that exceed the decibel readings of the engine's exhaust. To lessen the severity of this situation, some propeller manufacturers sacrifice aerodynamic efficiency by building club-like, square-end blades.

In contrast, in this invention equalized spacing of the small jet engines results in a constant balanced application of energy to the turbine buckets, and the firm, though movable, mounting of the blades between the hub and the U-channel insures positive, unvarying tracking free of noise-producing qualities, which makes it possible to employ the most efficient blade profile for air-moving purposes.

For large propeller assemblies, due to the weight, complexity of gear reduction boxes and attendant friction losses, shaft drive transmission is most costly from the standpoint of initial cost and most wasteful of energy from the operating standpoint, to say nothing of the expense in maintaining it in safe operable condition. Compared thereto, the present economical and highly efficient employment of energy, functioning as it does at the maximum leverage offered at the periphery of the rotor, permits light-weight construction and, what is perhaps of more importance, entirely eliminates gear transmissions and power losses associated with their use. Further, the U-channel may be constructed of a very light, corrosion-resisting alloy, adequately reinforced by stiffeners to withstand high peripheral stresses and other means whereby ruptures and what is known in aviation parlance as oil-canning may be avoided.

Inasmuch as the present craft is designed for vertical ascent and decent and inasmuch as it houses a separate powerplant, or plants for developing thrust for forward flight after sufficient altitude has been attained, no wing surfaces, runways or heavy undercarriage supports are required. By employing modern control features, the craft may arise or be set down in an area defined by its own dimensions.

Being shielded on all sides by the stator wall and the casing positioned exteriorally thereto, the propeller blades are totally unaffected by the movement of the craft through the air. Unlike the helicopter type of craft, whose blades must undergo variation in pitch twice per revolution due to being exposed in forward flight the propeller blades of the present invention may be constructed to yield the greatest aerodynamic efficiency.

To assist in control of the craft and to prevent unwanted sway during vertical ascent and descent, the several engines employed for turning the rotors may be fitted with controllable air intake means, such as de-

scribed in this applicant's pending application entitled Vestibule Air Intake for Jet Engines, Serial No. 752,879.

Also, an obvious requirement for controllable ascent and decent is the ability to alter the pitch of the propeller blades at will for moving air at varying volumes and velocities downstream. Toward that end, a tandem means is provided for varying as a single unit the pitch of both banks of propeller blades. And inasmuch as said blades are carried by bearings in the U-channel wall, as well as in the hub, they are designed to respond instantly to the slightest degree of change imposed by remote control upon them.

This type of craft may be constructed in any desired size or for any specific purpose, and the same relative efficiency may be obtained regardless of its proportional dimensions.

Other advantages inherent in this invention will become apparent as the herein description proceeds.

In the drawings:

FIG. 1 is, looking from the top, an over-all view of the aircraft embodying the vertical lift rotors, the encompassing stator walls, the fuselage and the exterior body constructions; also two jet engines shown in dotted outline for developing forward thrust, and a tail assembly for mounting of the control surfaces.

FIG. 2 is a reduced-size side view of the aircraft above described, showing therein the approximate position of the rotor assemblies.

FIG. 3 shows one of the several small jet engines with the branch-like tail pipe for discharging gas into the top and into the bottom bank of turbine buckets, the reverse flow of the gas therein as depicted by arrow means and the reactive drive discharge therefrom.

FIG. 4 is an enlarged detailed view of a rotor showing in the hub thereof a means for varying the pitch of the propeller blades, the method of movably mounting the blades in the wall of the U-shaped channel, a bank of turbine buckets and the turbine engines for focussing their output of motive fluid thereagainst; also, the discharge of the gas therefrom in a direction opposite to that of the rotors' rotation and the stator assembly mounted in close proximity to the buckets.

FIG. 5 is a fragmentary view of the stator assembly, showing in cross section the inturned flange at the top of the assembly's circular wall, the curved, angularly-mounted blades and a section of a gas turbine engine protruding at an angle through said wall for discharging its gas into the inner ends of the turbine buckets.

FIG. 6 is a fragmentary side view of a rotor, showing the supporting spider frame across its top, along one of its sides encompassing the stator wall and across its bottom. This figure also shows the rotor assembly mounted in bearings in the hubs of said frame, said assembly including the true-circle wall and the turbine buckets mounted to receive gas from the jet engine being shown in cross section.

FIG. 7 is an enlarged view showing a section of the channel wall that houses tapered bearings, a threaded bolt-like fitting riding via its tapered head on said bearings and means for securing a threaded sleeve in the tip section of a propeller blade.

FIG. 8 is a view showing the head of the tapered bolt-like fitting riding on the tapered bearings and the square slot in the head for turning it into its threaded sleeve, and

FIG. 9 is a frontal view of the tapered bearings against which said fitting makes anti-frictional contact.

Pure jet gas turbine engines **1**, of which there may be several, are shown in FIGS. 1, 3, 4 and in cross sectional fragmentary views in FIGS. 5 and 6. They generate the high-temperature, high-pressure motive fluid for driving rotors **2** and **3**, FIGS. 1, 4 and 6. As per directional arrow **4**, rotor **2** on the left-hand side of fuselage **5**, rotates in a clockwise direction while directional arrow **6** indicates rotation of rotor **3** in a counter-clockwise direction. As aforesaid, the torque developed by one rotor neutralizes the torque developed by the other.

As shown in FIG. 3, tail pipe **7** of the several engines **1**, has a converging formation that has, in turn, two diverging outlet branches, one branch directing gas into buckets **8**, which are secured to the underside of top flange **20**, and the other branch into buckets **9** which are secured to the top side of bottom flange **21**. The buckets are also secured to true-circle wall **19**, as per screw bolts **35**, FIG. 4.

Both banks of buckets **8** and **9** are of similar construction except that buckets **8** take in motive fluid through aperture **10** formed partially in the side of the buckets facing engines **1** and partially through their bottoms, as depicted in FIG. 3, whereas buckets **9** receive their fluid through aperture **11** formed partially in the side of the buckets facing engines **1** and partially through their tops.

As shown in FIG. 4, in buckets designated **8**, these apertures are formed in the inboard section of the buckets, arrows **12** depicting the flow of the fluid to the interior thereof.

Upon the fluid striking the rounded rear side of the buckets, as depicted by flow arrows **12**, FIGS. 3 and 4 and as shown in buckets carrying the numeral **8**, its impingement thereagainst drives the buckets in their rotative cycle.

Simultaneously, due to the high-peripheral speed of the buckets, the centrifugal force generated within the fluid momentarily occupying the buckets builds up pressure therein. This compression pressure, in turn, converts into velocity pressure and, as will be noted by referring to the construction of the buckets the top, the rear side and the outer ends thereof converge to form orifice **14** at the buckets' radial extremities.

To assist in maintaining fluid pressure within the buckets, guide elements **13**, shown in dotted outline, FIG. 4 are formed therein, around which the fluid is forced to flow.

Orifice **14** is formed in an offset construction of the forward face and the outer end of the buckets, shown in cross section in FIG. 3. The purpose of this offset is two-fold: One, to prevent interference between the fluid discharging from one bucket and the bucket following next in rotation and, two, to cause the fluid to strike stator blades **15** mounted on stator wall **16** for downward thrust to atmosphere, as indicated by arrows **17**, FIG. 5.

Upon observing FIG. 5, it will be noted that the stator blades are mounted angularly against circular wall **16**. Although the angle of mounting is relatively slight and inasmuch as the inturned flange on the top of the wall prevents escape of the fluid upwardly, said mounting will insure downward discharge of the fluid. Moreover, as shown in FIGS. 1, 4 and 5, blades **15** are curved to contain the fluid striking against them and convey it downwardly to atmosphere.

As shown in FIGS. 1, 4 and partially in the main part of FIG. 5, engines **1** are positioned in body **47** of the craft supporting stator wall **16**, through which, as shown in FIG. 5, the engines pass into the space between buckets **8** and **9** to discharge their fluid through their branch-like tail pipes into these buckets, as previously set forth.

Being mounted on the periphery of the rotors, the peripheral speed of the buckets is great. Inasmuch as four gas-producing engines are suggested, the pressure in the fluid output will be practically constant as the buckets sweep past the branches of the tail pipes.

Propeller blades A, B, C and D of the top bank and blades E, F, G and H of the bottom bank are secured respectively in the top and bottom parts of propeller hub **18**, as shown in side view, FIG. 6. These blades, besides performing their usual function, serve as spokes for supporting the turbine construction carried on their tips, which construction must be made as light as possible to counteract gravitational pull.

As indicated in FIGS. 4 and 6, bevel gears **22** are

mounted on the inner ends of extension fittings 23, which are integrated with the propeller blades. These gears, in conjunction with liner 30, which abuts the inner surface of hub 18, carry therebetween ball bearings 52, said bearings absorbing the radial thrust of the propeller blades. These bearings also permit controlled movement of the blades for variable pitch purposes.

Propeller hub 18 is mounted concentrically around centrally positioned shaft 24, shown in FIGS. 1, 4 and 6. This shaft, in turn, is positioned between bearings 25 and 26, mounted in the hub section of supporting frame 27, the radiating arms of which extend laterally to envelop stator ring 16 and continue to engage the hub section of frame 27 at its bottom. Shaft 24 is locked in position by lock nut 28 at its top and bevel gear 29 at its bottom.

Bevel gears 22—there is one for each of the blades in each bank of four blades—are driven collectively as a unit by bevel gears 31 and 32 which are secured to shaft 24, as indicated by keys 53. Bevel gear 29 is secured to said shaft at its bottom, being mounted thereon underneath the bottom hub. This latter gear is driven by gear 33 secured on shaft 34; which shaft, in turn, may be connected to a source of power in the fuselage. Gears 22, 31 and 32 inside the hub rotate with it, as does also gear 29 on the exterior thereof, which latter gear, as aforesaid, is engaged by gear 33. A clutch, not shown, may be employed for transmitting power to the hub shaft.

Shaft 34 extends through roller bearings 36, which assemblies are secured by flange means 37 to an arm of supporting frame 27. Shield 38 weatherproofs bearings 25 at the top of the hub section of frame 27 and shield 39 weatherproofs gear 29, gear 33, shaft 34 and bearings 36 as well as shaft bearing 26.

The several propeller blades are secured to true-circle wall 19 by means of a threaded sleeve 40 inserted in the tips thereof, shown in detail in FIG. 7, and secured by riveting or similar means, such as at 41. Tapered roller bearings 42 are inserted in seats provided in wall 19. These bearings may be reinforced by a surface liner, depending on the gauge of metal used in the construction of wall 19. Form-fitting bolt-like fittings 43 are provided to threadably engage sleeves 40 in the propeller tips, the heads of said fittings riding anti-frictionally against bearings 42, thus providing movable engagement of said wall to said propeller blades.

Buckets 8 and 9 are secured to top and bottom U-channels 20 and 21 respectively by means of screw bolts 44. FIG. 6 and also shown in FIG. 4. As shown in FIG. 6, stiffeners 45 may be provided on the outer side of true-circle wall 19 to serve as reinforcements therefor.

Stator wall 16 is secured to the outer body of the aircraft by means of cleats 46 engaging the inturned flange of said wall and the aircraft body construction, designated 47. The direction of the air intake of engines 1 is indicated by arrows 48, which have a small circle on their tips. In contrast, the arrows depicting the flow of the high-pressure motive fluid have forked tails.

Fuselage 5, mounted between rotors 2 and 3, comprises part of the aircraft's construction. Its curved leading edge is shown forward of the rotors and it may carry a conventional type of tail assembly 49, which includes lateral and longitudinal directional control surfaces. Although no runway is required for this craft, undercarriage 50 is shown in FIG. 2, to be employed mainly for ground manoeuvering purposes. And as previously stated, this craft is powered by one or more pure jet engines for developing forward thrust, such as those shown in dotted outline in FIG. 1 and identified as 51..

Having described my invention, I claim:

1. An impulse and reactive tip-driven rotor mounted for rotation in a supporting construction, said rotor being comprised of a hub, a distantly spaced turbine structure positioned concentrically to said hub and a plurality of propeller blades occupying the area therebetween, said blades having one end movably secured in said hub and the other end movably secured in said structure, said blades having movable connection with means in said hub to uniformly vary the pitch thereof for moving air at various volumes and velocities downstream, said structure being comprised of an upright true-circle wall paralleling said hub and having a top and a bottom flange extending outwardly therefrom to form a U-shaped channel, a plurality of buckets secured in said channel at the conjunction of the inner side of said top flange and said true-circle wall and a like number of buckets secured in said channel at the conjunction of the inner side of said bottom flange and said true-circle wall, each of said buckets having an intake aperture adjacent said conjunctions, a space provided between said top and lower buckets, a stator ring mounted in said supporting construction, said ring being concentrically spaced outwardly from and paralleling said true-circle wall and having a depth co-equal therewith, said ring having a closed top formed by a right-angular flange extending inwardly to within close proximity of the top flange of said true-circle wall, a number of pure jet gas turbine engines mounted in said supporting construction for supplying motive fluid to said turbine structure, each of said engines having a tail pipe extending through said stator ring into said space and terminating between and within close proximity of said buckets for focussing said fluid via said apertures into the confines thereof, said buckets having walls forming a reverse-curving back and an orifice at their radial extremities, said orifices facing to discharge said fluid from the radial extremity of said buckets in a direction opposite to that of the rotor's rotation, a plurality of vanes secured to said stator ring flange and to the inner surface of said ring at substantially right angles thereto, said discharge being directed against said vanes for the downward conveyance of said motive fluid to atmosphere.

2. The rotor as described in claim 1 wherein a propeller hub comprising an annular hollow structure has a depth co-equal with that of said true-circle wall, said structure having a removable top and a removable bottom plate capping the ends thereof, a centrally positioned shaft extending through and being secured to said plates, said shaft being anti-frictionally mounted to receive turning effort from a source in said supporting construction, said hub having a number of openings through the sides thereof for allowing the entry of the inner ends of said propeller blades, said ends being movably secured therein to means having engagement with said shaft.

3. The rotor as described in claim 1 wherein a plurality of blades have ends positioned between anti-frictional bearings within said rotatable propeller hub, said blade ends being mounted to comprise a coordinated unit movable independently of the rotation of said hub and at a uniform pitch.

4. The rotor as described in claim 1 wherein said hub has a top and a bottom end, said hub having a multi-bladed propeller assembly movably secured adjacent the top end and another multi-bladed propeller assembly movably secured adjacent the bottom end, said true-circle wall being divided into degrees, the blades of the top assembly being positioned at 0, 90, 180 and 270 degree locations and the blades of the bottom assembly at the 45, 135, 225 and 315 degree locations, said blades being mounted equi-distantly between said hub and said wall for lending uniform anti-gravitational centrifugal stress support thereto.

5. The rotor as described in claim 1 wherein said true-circle wall has a plurality of tapered bearing assemblies secured on the outer side thereof, said bearings providing anti-frictional surfaces for the mounting of said propeller blades in said turbine structure, a like number of apertures extending through said wall to coincide with the centers of said bearing assemblies, an equal number of fittings having heads shaped to fit and ride on said surfaces, said fittings extending freely through said apertures and being made secure to the tip ends of said propeller blades.

6. The rotor as described in claim 1 wherein said turbine buckets have a radial length greater than that of their depth, an inner end abutting said upright wall and a top, a bottom and a curved rear side converging to comprise the radial extremity thereof, the walls of said buckets being formed to provide an intake aperture at said inner end for receiving said motive fluid, a discharge orifice at said radial end and a guide member positioned between said intake aperture and said orifice for directing the internal flow of said motive fluid prior to the discharge thereof through said orifice in a direction opposite to that at which said fluid was received in said buckets.

7. The rotor as described in claim 1 wherein said construction supports a plurality of pure jet gas turbine engines for discharging motive fluid into said buckets, a tail pipe secured to each engine, said pipe having a converging throat and diverging branch-like sections, one branch inclining upwardly for directing said fluid into said top buckets and another branch declining downwardly for directing said fluid into said lower buckets.

8. The rotor as described in claim 1 wherein said buckets have walls forming an orifice at the radial extremity thereof, a structural offset provided at said extremity, said orifice being located in said offset for directing the discharge of motive fluid from said buckets against the vanes of said stator ring in a direction opposite to that of the rotor's rotation.

9. The rotor as described in claim 1 wherein said stator vanes have a top and a bottom end and a curved construction facing the orifices of said buckets for receiving the discharge of said motive fluid therefrom, said vanes being mounted non-perpendicularly on said stator ring relative to the annular contour thereof, the bottom end slanting farther from the perpendicular relative to the top end for assisting the flow of said fluid partially in the direction in which it was discharged from said orifices and partially in a downward direction.

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