July 6, 1948. L. H. LEONARD 2,444,781

AXIAL FLOW HELICOPTER

Filed Dec. 8, 1943 2 Sheets-Sheet 1

Fig. 1

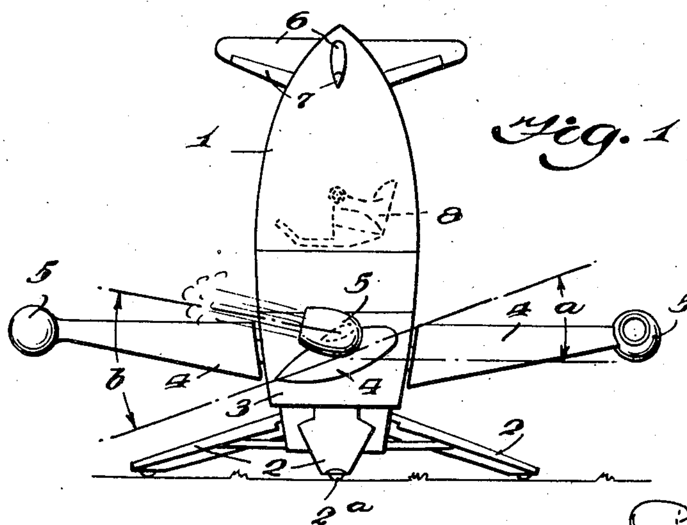


Fig. 2

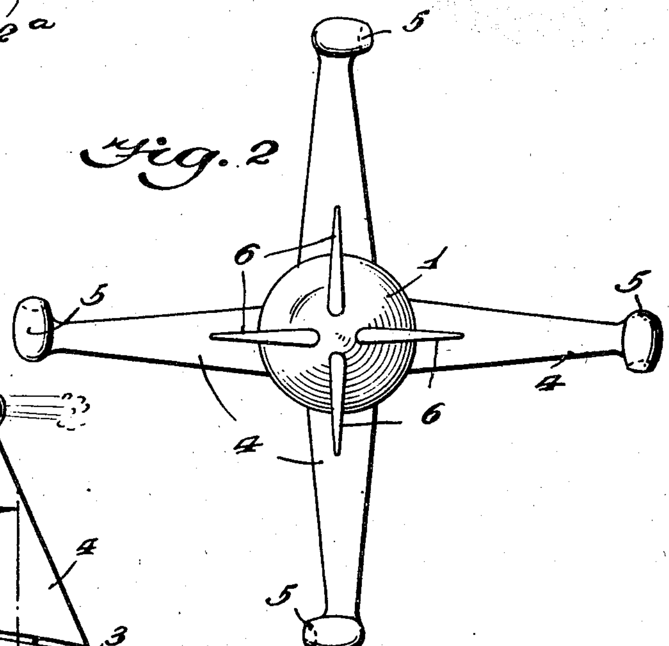
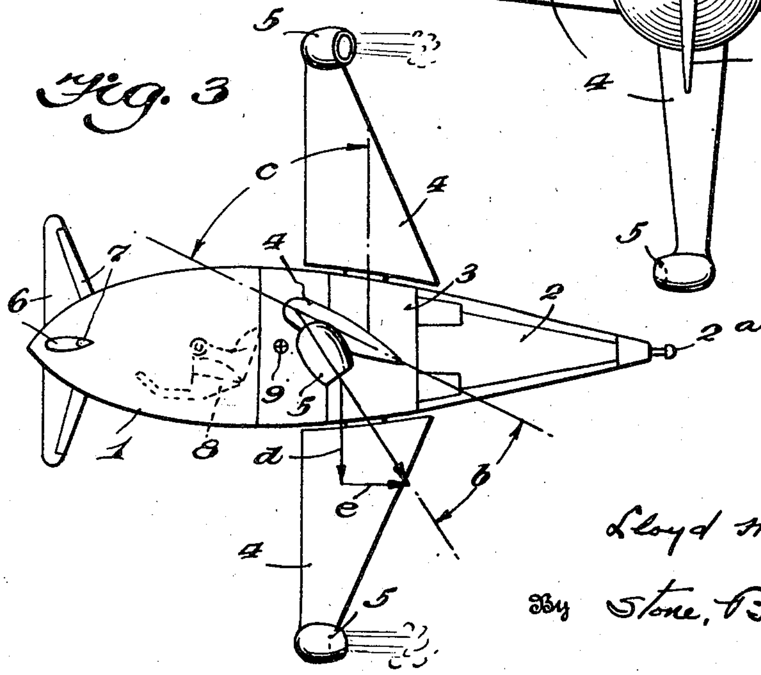


Fig. 3



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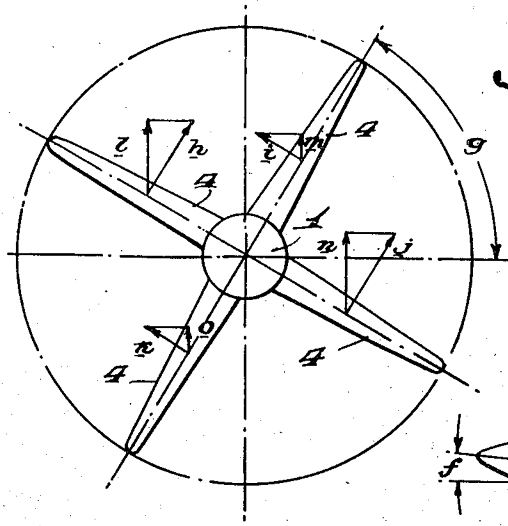

Fig. 4

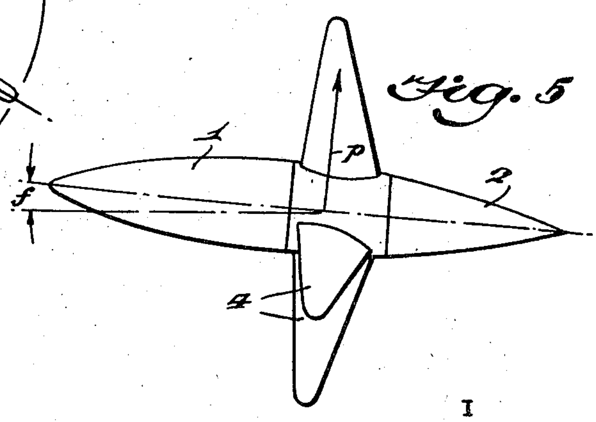

Fig. 5

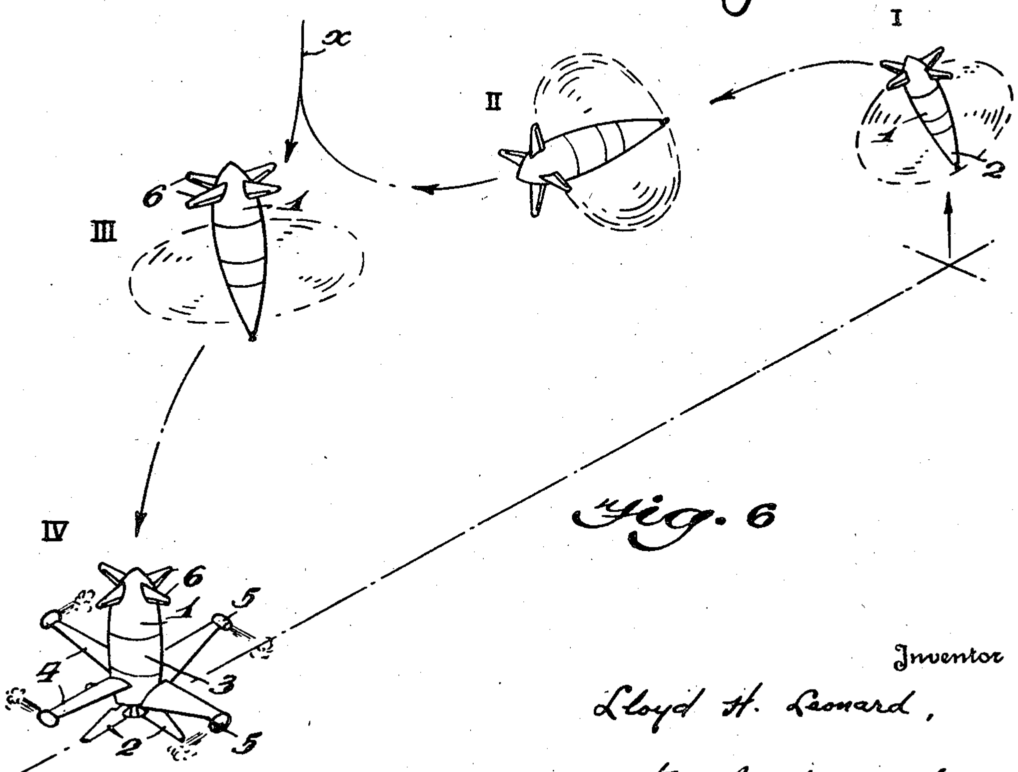

Fig. 6

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AXIAL FLOW HELICOPTER

Lloyd H. Leonard, New York, N. Y.

Application December 8, 1943, Serial No. 513,423

4 Claims. (Cl. 244—7)

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This invention relates to aircraft, and particularly to craft capable of both vertical and horizontal flight, after the manner of a helicopter. More specifically, the invention relates to aircraft of this type having propeller blades driven by combustion jets.

One of the objects of the invention is to provide jets so mounted on variable pitch blades that, when said blades are set to high pitch, as for horizontal flight, the direction of discharge of the jets is such as to generate a forwardly acting thrust component.

Another object is to devise a propeller so constructed and mounted as to itself supply the lift necessary to sustain the craft in horizontal flight, without the use of wings, and to provide control means for shifting the craft from vertical to horizontal flight attitude, or vice versa, as desired.

With the above and other objects in view, the invention consists in the construction and arrangement of parts hereinafter described and claimed, and illustrated in the acocmpanying drawings, forming part of this specification, and in which:

Fig. 1 is a side elevation of my improved aircraft as it appears when resting upon the ground in position for taking off.

Fig. 2 is a front end view of the same as it appears in flight.

Fig. 3 is a side elevation of the aircraft shown in Fig. 1 as it appears when in horizontal flight.

Figs. 4 and 5 are diagrammatic views illustrating the principle of the four blade propeller which I prefer to employ; and

Fig. 6 is a schematic view in perspective illustrating the method of flight of my improved aircraft.

Referring to the drawings in detail and particularly first to Figs. 1–3, my improved aircraft comprises an elongated body or fuselage **1**, adapted to be supported upon the ground in upright position on legs or landing gear **2**, as shown in Fig. 1. This landing gear, when the craft is in flight, is collapsed or closed, as shown in Fig. 3, so as to constitute a continuation of the streamlined body. At the extreme end of the landing gear is a contact rod **2a** which is adapted to engage the ground when the craft descends and thus trip the landing gear into open position, as shown in Fig. 1. This landing gear may be substantially similar to that illustrated and described in more detail in my prior copending application, S. N. 375,991, filed January 25, 1941, which matured into Patent No. 2,387,762, October 30, 1945.

As in my said prior co-pending application, the body of the present craft is formed with a rotatable section **3**, conforming with the body and carrying a plurality of propeller blades **4**, projecting radially therefrom. As hereinafter more fully explained, I prefer to employ 4 equally spaced similar blades, as illustrated in Fig. 2.

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While in my said prior co-pending application I have illustrated propeller sections or rotors driven by means of an engine, in the present case I propose to drive my improved propeller by means of combustion jets **5** mounted on the propeller blades preferably adjacent the tips thereof. In this respect, the present design is similar to that of my prior co-pending application, S. N. 505,207, filed October 6, 1943, the differences between the two designs being, however, that in said prior application the blades are held stationary during horizontal flight, while in the present design the blades rotate continuously during both vertical and horizontal flight.

The present invention likewise contemplates the provision of means for varying the pitch of the blades at will. Such means is not illustrated herein in detail, but may be of the nature illustrated and described in either one of my above mentioned prior co-pending applications.

As hereinafter more fully explained, the use of a propeller having four similar blades renders unnecessary the employment of any wing surface whatsoever. It is desirable, however, to provide fin surfaces to aid in stabilizing the craft during vertical flight and these are preferably mounted adjacent the nose of the craft, as shown at **6**. Each of these fins is preferably provided at its trailing edge with angularly adjustable control surfaces or ailerons **7**. By adjusting these ailerons, it is not only possible to shift the craft from vertical to horizontal flight attitude as desired, but also to provide means for counteracting the bearing friction of the rotor and thus prevent the fuselage from rotating about its longitudinal axis. For this latter purpose the ailerons may be set at such an angle as to produce an aerodynamic torque sufficient to overcome the drag due to the bearing friction of the rotor.

The pilot's compartment, as in my said prior co-pending applications, is located in the forward part or nose of the craft and the pilot's seat, which is shown at **8** in dotted lines in Figs. 1 and 3, is mounted on a pivot so that the pilot is maintained in upright position regardless of the variations in the position of the fuselage itself as it shifts from vertical to horizontal flight.

As explained in the first of my above identified prior co-pending applications, it is desirable to set the blades at relatively low pitch while climbing in vertical flight and to shift them to relatively steep or high pitch when in horizontal flight. Thus, in Fig. 1, I have shown the blades **4** set at such low pitch that the chord line through the base of the blade makes a relatively small angle a with the plane of rotation, while in Fig. 3 the blades are illustrated as set at a higher pitch so that this chord line makes a much larger angle c with the plane of rotation.

By reference to Figs. 1 and 3, it will be further noted that the jets **5** are mounted on the blades in such a position that the direction of discharge lies at an acute angle b to the chord line through the base of the blade, at the rear or trailing side of the blade. Owing to this angular arrangement, it will be seen that when the blades are set at low pitch, as shown in Fig. 1, for vertical flight the jet will generate a small downward thrust component. This, however, is not seriously objectionable, because such downward component is negligible compared with the upward thrust due to the rotor blades themselves.

When, however, the blades are shifted to higher pitch, as shown in Fig. 3, this angular relation of the direction of jet discharge to the chord line of the blade results in the creation of a forwardly acting thrust component. As illustrated in Fig. 3, the jet produces a relatively large tangential thrust component d, in the plane of rotation of the blades, and a relatively small axial forward thrust component e. While this forward thrust component is small as compared with the thrust of the blades themselves, it nevertheless acts with and augments the thrust of the blades thus aiding in the compulsion of the craft. The angle b should therefore be so chosen that the downward thrust component of the jet, when the blades are set at low pitch, as shown in Fig. 1, is negligible, while, at high pitch, as shown in Fig. 3, there is a substantial forward thrust component, it being understood that in all cases it is desirable to have the thrust component acting tangentially in the plane of rotation as great as possible.

It is intended that the rotor blades be so positioned as to operate in a plane somewhat to the rear of the center of gravity of the craft, as indicated at **9** in Fig. 3. It is evident that in this case it will be necessary, in order to trim the machine in horizontal flight, that a lifting force be applied at a point forward of the center of gravity. This lifting force may be supplied by slightly deflecting the ailerons **7** of the horizontal fins **6**, or, since it is contemplated that the craft will be flown with the center line of the fuselage inclined slightly upwardly, as shown in Fig. 5, that is to say, at a slight angle of attack relative to the direction of flight, the lift due to the action of the fuselage itself will be adequate to trim the machine, even without fins or ailerons.

The aircraft of the present design, as well as those of my two prior co-pending applications, above identified, may be defined as of the axial flow helicopter type, since the flow of air past the rotor is axial at all times, in both vertical and horizontal flight. This is in sharp contrast to helicopters of the conventional design.

In Fig. 6, I have illustrated the method of flight of my improved aircraft. At I the craft is shown after having taken off, and at the point of changing from vertical to horizontal flight.

At II it is shown in horizontal flight. When it is desired to land, the controls are separated so as to pull the craft up into vertical position, as indicated at x, and it is then allowed to drift downwardly, tail first, as shown at III. It finally lands in the position shown at IV with the supporting legs or landing gear spread apart, as illustrated.

The principles underlying the use of a four bladed rotor to sustain the craft in horizontal flight will now be briefly discussed. In this connection, attention is called to Figs. 4 and 5, constituting diagrammatic end and side views, the propulsion jets being omitted for the sake of clearness. Obviously, the principle of operation is the same whether the propeller is driven by jets or by some other means.

The theory of the lifting propeller is based upon the assumption that the axis of rotation of the rotor must be slightly inclined with respect to the direction of flight. This is indicated in Fig. 5, in which the axis of the rotor, which corresponds with the longitudinal axis of the fuselage, is inclined to the direction of flight at a small angle f. This is commonly referred to as the "angle of attack."

It is a well recognized principle that the resultant aerodynamic force acting upon a wing shaped element or blade acts in a direction substantially perpendicular to the longitudinal axis of such element or blade.

In the force diagram of Fig. 4, assuming that the blades are in full feathered position, the vectors h, i, j and k represent the resultant forces, due to the angle of attack acting on the four blades in a direction at right angles thereto, and the vertical components of these resultant forces are represented by the vectors l, m, n and o, and it is apparent that the total lifting effect of the four blades will be the sum of these vertical components, as indicated by the vector p, in Fig. 5.

The vertical component, for any particular blade, varies with the angle g which such blade makes with the horizontal, at any given instant, and is proportional to the cosine of this angle. For example, the vertical component m is equal to $i \cos g$.

The effective angle of attack varies with the angular position of the blade, being, for the assumed case of full feathered blades, a maximum when the blade is horizontal, and zero when the blade is vertical. Thus, it varies as the cosine of the angle g.

As above stated, each vertical component of the resultant forces due to the angle of attack varies as the cosine of the angle g, for example, referring to Fig. 4, $m=i \cos g$.

But, as heretofore explained, the resulting forces such as i, due to the angle of attack, also vary as $\cos g$. Hence, the magnitude of the vertical component m, for different positions of the blade, varies as $\cos^2 g$.

Since the propeller has four blades, comprising two pair at right angles to each other, it follows that the vertical component or lift on a blade disposed at 90° to that above considered is obviously proportional to the square of the sine of said angle g.

But,

$$\sin^2+\cos^2=1$$

Hence, the total lift developed by the cross-wind forces on all of the blades, due to the inclination of the thrust axis, or angle of attack, is constant, for all positions of the blades, and is thus seen to be unaffected by their rotation.

It can be shown that any variation of pitch from the full feathering position, such as shown in Fig. 5, will also produce a uniform lift as the blades rotate.

What I claim is:

1. An aircraft capable of both vertical and horizontal flight and comprising an elongated fuselage, a single set only of propeller blades rotatable in a common plane about the longitudinal axis of said fuselage at a point behind the center of gravity, said fuselage having no wings or tail surfaces whatever, said blades, with the fuselage itself, constituting the means for sustaining the craft during flight, and fins projecting radially from the nose portion of the fuselage and having angularly adjustable control surfaces thereon.

2. An aircraft capable of both vertical and horizontal flight and comprising an elongated fuselage, a single rotor mounted to revolve about the longitudinal axis of said fuselage at a point intermediate its ends, and having four equally spaced, similar blades projecting substantially radially therefrom, said fuselage having no wings or tail surfaces whatever, said blades constituting the sustaining means in horizontal flight, and fins projecting from the nose of said fuselage and having adjustable control surfaces thereon.

3. An aircraft capable of both vertical and horizontal flight and comprising an elongated fuselage, a single rotor mounted to revolve about the longitudinal axis of said fuselage at a point adjacent but rearward of the center of gravity thereof, and having four equally spaced, similar blades projecting substantially radially therefrom, said fuselage having no wings or tail surfaces whatever, said blades, with the fuselage itself, constituting the means for sustaining the craft during both vertical and horizontal flight, and control means for shifting the craft from vertical to horizontal flight attitude, when desired.

4. An aircraft capable of both vertical and horizontal flight and comprising a wingless elongated fuselage, a single jet propelled rotor mounted to revolve about the longitudinal axis of said fuselage at a point intermediate its ends, and constituting the sole propelling means for said craft, and means located forward of said rotor for counteracting the torque due to the bearing friction of the rotor, so as to prevent the craft from rotating about its longitudinal axis.

LLOYD H. LEONARD.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,191,501	Dees	July 18, 1916
1,262,660	Gallaudet	Apr. 16, 1918
1,686,080	Ford	Oct. 2, 1928
2,003,206	Lewis	May 28, 1935
2,022,476	Myers	Nov. 26, 1935
2,043,704	McPherren	June 9, 1936
2,142,601	Bleecker	Jan. 3, 1939
2,300,268	Stuart	Oct. 27, 1942
2,328,786	Crowder	Sept. 9, 1943
2,397,357	Kundig	Mar. 26, 1946