Dec. 14, 1954 A. M. LIPPISCH 2,696,953

FLUID PROPELLED AIRPLANE

Filed March 9, 1951 2 Sheets-Sheet 1

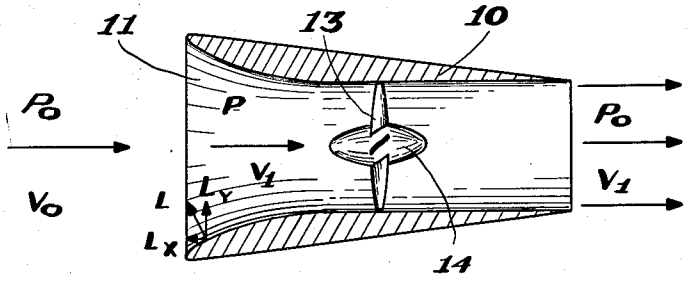


Fig 1

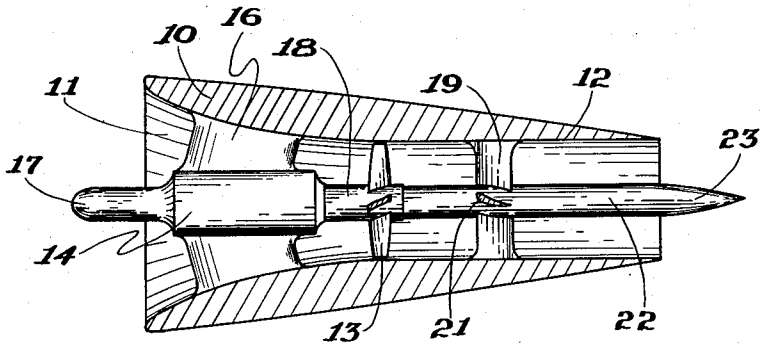


Fig 2

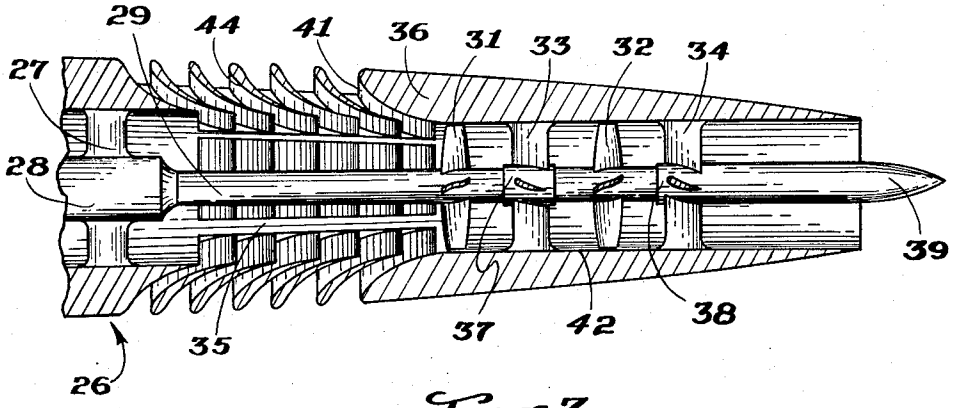


Fig 3

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FLUID PROPELLED AIRPLANE

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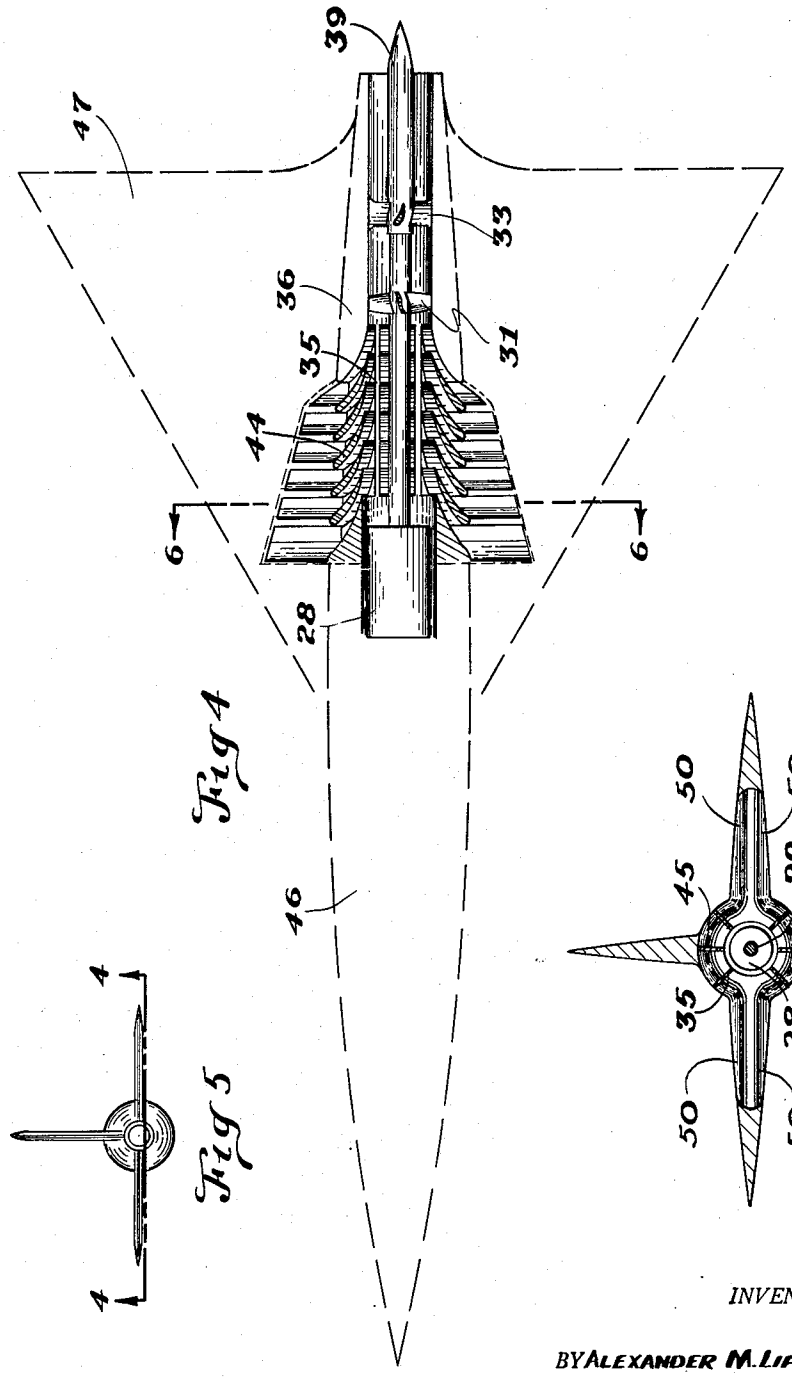


Fig 4

Fig 5

Fig 6

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FLUID PROPELLED AIRPLANE

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3 Claims. (Cl. 244—15)

This invention relates in general to means for increasing the power that may be put into a propeller, and in particular, to the combination of a propeller mounted in a shrouding means to obtain a very high efficiency.

It is oftentimes necessary to limit the diameter of a propeller in order to keep the tip of the propeller at a speed below the transonic range. The reason for this is that as the tip reaches a velocity near the speed of sound, a barrier is formed and the efficiency of the propeller decreases. Also, when a pusher type propeller is being used on an aircraft, the length of the propeller must be such that it does not hit the ground when the plane is in a landing attitude. The problem is therefore presented of getting the maximum amount of power into a propeller of fixed diameter.

It is an object of this invention, therefore, to provide means for increasing the thrust obtainable with a propeller of fixed diameter.

Another object of this invention is to eliminate torque resulting from rotation of a propeller and its power plant.

Still another object of this invention is to greatly increase the efficiency of a propeller.

Yet another object of this invention is to provide a shrouded propeller wherein the configuration of the shroud in combination with the propeller gives a greatly increased thrust as compared to an open propeller.

A feature of this invention is found in the provision for a propeller mounted in a tube which has the shape of an air-foil-section so as to obtain a greatly increased efficiency for the propeller.

Further objects, features and advantages of this invention will become apparent from the following description and claims when read in view of the drawings, in which:

Figure 1 illustrates a cross-sectional view of an air-foil section tube with a propeller mounted therein;

Figure 2 illustrates a sectional view through an air-foil section tube with a driving means, propeller, and straightening baffles mounted therein;

Figure 3 is a sectional view of an air-foil section tube with two propellers and counter baffles mounted therein;

Figure 4 is a sectional view taken on a line 4—4 of Figure 5 and illustrates the power plant of this invention mounted in a delta wing aircraft;

Figure 5 is a rear view of a delta wing aircraft; and

Figure 6 is a sectional view taken on line 6—6 of Figure 4.

The ideal efficiency of an open propeller (one which is unsurrounded by any material) is given by the equation:

$$\eta_{ideal}=\frac{2}{1+\sqrt{1+C_T}} \tag{1}$$

where C_T is defined as the disc loading coefficient and is determined by:

$$C_T=\frac{\text{Thrust}}{\text{Disc area}\times\text{Stagnation pressure}} \tag{2}$$

or

$$C_T=\frac{T}{\frac{\pi}{4}D^2\frac{\rho}{2}V^2} \tag{3}$$

where

T=thrust
D=propeller diameter
ρ=density of air
V=velocity of air

The reduction of the propeller diameter has its largest influence in the low speed range where the stagnation pressure is low and the low speed thrust is considerably reduced because there is too high disc loading. The reduction of the static and low speed thrust has a very bad influence on the length of the take-off run especially with high speed airplane configurations which necessarily have high wing loadings.

Applicant has discovered that the efficiency of a propeller can be substantially increased by mounting it in a tube with a cross-sectional configuration such as shown in Figure 1. Figure 1 illustrates a tube **10** which is formed with a forwardly curved portion **11** that joins a straight section. Tube **10** might be described as trumpet-shaped and in thickness represents an air-foil-section as shown.

A propeller **13** is mounted in the tube adjacent the inner end of the straight section **12**. The propeller is driven by a suitable driving means, not shown in Figure 1 for the reason that this figure is used to illustrate the theoretical principles of the invention.

Air is impelled through the tube **10** in the direction of the arrows. Assuming that the outside air forwardly of the tube **10** has a pressure of P_0 and a velocity of V_0, then the propeller **13** will draw air into the tube **10** and increase its velocity to V_1 and decrease its pressure to P. The propeller increases the pressure without changing the velocity which must stay constant in a tube of constant cross-section. The pressure behind the propeller must be equal to the outside pressure and from the theory of flow it is known that this static pressure must be the same as the external pressure P_0. The pressure differential created by the prop therefore is:

$$\Delta P=P_0-P \tag{4}$$

According to Bernoulli's law the incoming flow is described by:

$$P_0+\frac{\rho}{2}V_0^2=P+\frac{\rho}{2}V_1^2 \tag{5}$$

or

$$P_0-P=\frac{\rho}{2}(V_1^2-V_0^2) \tag{6}$$

Thrust developed by the propeller **13** and tube **10** is equal to the increase in momentum or:

$$T=M_s(V_1-V_0) \tag{7}$$

where T is thrust and M_s is the mass per second which is accelerated and is equal to:

$$M_s=\frac{\pi}{4}D^2\rho V_1 \tag{8}$$

Substituting this value of M_s in the above equation:

$$T=\rho V_1(V_1-V_0)\frac{\pi}{4}D^2 \tag{9}$$

is obtained.

The thrust coefficient is defined as:

$$C_T=\frac{T}{\frac{\pi}{4}D^2\frac{\rho}{2}V_0^2} \tag{10}$$

Substituting the value of T obtained from Equation 10 in Equation 9:

$$C_T\frac{\pi}{4}D^2\frac{\rho}{2}V_0^2=\rho V_1(V_1-V_0)\frac{\pi}{4}D^2 \tag{11}$$

or

$$C_T=2V_1\frac{(V_1-V_0)}{V_0^2}=2\frac{V_1}{V_0}\left(\frac{V_1}{V_0}-1\right) \tag{12}$$

is obtained.

Solving for

$$\frac{V_1}{V_0}$$

$$\frac{V_1}{V_0}=\frac{1}{2}(1\pm\sqrt{1+2C_T}) \tag{13}$$

is obtained.

The power required to compress the air going through the propeller from P up to P_0 is equal to the volume per second times the pressure differential required or:

(14) $$\text{Power}=\frac{\pi}{4}D^2V_1(P_0-P)$$

Substituting the value of P_0-P from Equation 6,

(15) $$\text{Power}=\frac{\rho}{2}V_1(V_1^2-V_0^2)\frac{\pi}{4}D^2$$

is obtained.

The efficiency is defined as the ratio of output or effective power to the necessary required input power:

(16) $$\eta=\frac{\text{Thrust}\times\text{speed}}{\text{Power required}}$$

or

(17) $$\eta=\frac{\rho V_1(V_1-V_0)\frac{\pi}{4}D^2V_0}{\frac{\rho}{2}V_1(V_1^2-V_0^2)\frac{\pi}{4}D^2}$$

or

(18) $$\eta=\frac{2V_0}{V_1+V_0}$$

This is the same formula as the well-known Rankine-Froude equation, but here V_1 is also the speed through the propeller disc.

Dividing the numerator and denominator of Equation 18 by V_0

(19) $$\eta_{\text{ideal}}=\frac{2}{\frac{V_1}{V_0}+1}$$

is obtained.

Substituting the value of

$$\frac{V_1}{V_0}$$

from Equation 13 and multiplying numerator and denominator by two gives:

(20) $$\eta_{\text{ideal}}=\frac{4}{3+\sqrt{1+2C_T}}$$

Comparing the open propeller with a propeller in a tube having the same thrust coefficient we obtain the equation:

(21) $$\frac{\eta_{\text{tube}}}{\eta_{\text{open}}}=\frac{2+2\sqrt{1+C_T}}{3+\sqrt{1+2C_T}}$$

From this formula it is observed that approaching zero speed where C_T approaches infinity, the efficiency ratio becomes the square root of 2 which equals 1.414. Thus the theoretical increase in efficiency of the propeller in a tube is 41% greater than the efficiency of an open propeller.

The ratio of thrust in the two cases is $\sqrt{2}$ or 1.260. Thus, a theoretical increase of 26% in the static thrust is obtained over an open tube. The increase in thrust is due in part to configuration of the tube. Lift is developed normal to an air-foil-section and on the curved portion **11**, the lift vector L, extends slightly in the forward direction. This gives a forward lift component L_x and a lateral lift component L_y. The lateral lift components L_y are balanced by components about the periphery, but the forward components L_x add together to give a forward thrust.

Applicant's Figure 2 illustrates a practical embodiment for the principles illustrated in Figure 1. The tube **10** is generally trumpet-shaped, as in Figure 1, and has mounted within the larger portion **11**, a driving means **14** which is supported within the tube by holding brackets **16**. The forward end of the driving means **14** has a streamlined projection **17** so as to maintain smooth flow by the driving means. The output shaft **18** of the driving means **14** is connected to a propeller **13** which is mounted at the end of the curved portion **11**. It is to be understood that the curved portion **11** must be convex to obtain the advantages of the invention.

Mounted rearwardly of the propeller **13** in the straight portion of the tubes **12** are a plurality of counter vanes **19**. These counter vanes are set so as to deflect the flow of air through the tube and to eliminate the rotational motion caused by the propeller **13**. The vanes **19** are formed so as to be air foil sections, as shown by the section **21** through the vane. The vanes in addition to straightening out the flow of fluid through the tube, also exert a forward thrust on the tube **10** due to their air foil configuration. There will be a forward thrust component developed on the vanes in a manner similar to the forward thrust L_x developed on the curved portion **11**.

A longitudinal rod **22** is fastened to the junction point of the vanes **19** and has an outwardly extending end **23** which comes to a point to obtain a streamlined air flow. The opposite end of the member **22** is rotatably connected to the shaft **18** to give it longitudinal support.

Applicant has discovered that the increase in static thrust of his apparatus shown in Figure 2 over an open propeller of the same size is greater than the theoretical increase of 26% and was in fact more than 30%. One reason for this increase is that in the open prop there is usually no recovery of the rotational momentum of the slip stream. Applicant's vanes **19** obtain lift from the rotational components of slip stream and thus increase the efficiency. The propeller in the tube also has a lower disc loading for the same thrust conditions. The thrust developed by the propeller in the tube is due to the pressure differential on opposite sides of the propeller and also from the suction obtained due to the trumpet-shaped intake **11** and the configuration of the vanes **21**.

The power plant illustrated in Figure 2 is designed for speeds up to the transonic zone. For example, the power plant could be mounted in the wings of an aircraft, or it might be mounted rearwardly on top of the fuselage and extend upward above the fuselage.

For high speed flight propulsion, however, the upwardly extending power plant and tube would be unfavorable because the configuration of the front of the tube would develop a shock wave and greatly increase drag. Under such conditions it is deemed advisable to mount the power plant within the fuselage of the aircraft, as shown in Figure 3.

Figure 3 illustrates the fuselage of an aircraft designated generally as **26** which has mounted therein by the brackets **27** a driving means **28**. A tube **36** similar to tube **10** of Figure 2 is connected to the fuselage **26** with longitudinal supporting means **35**. The driving means **28** has an output shaft **29** which extends rearwardly into tube **36** and has mounted thereon a pair of propellers **31** and **32**. Air-foil-section counter vanes **33** and **34** are mounted to the tube **36** behind the propellers **31** and **32**, respectively.

The shaft **29** passes through bearing means **37** at the junction of the vanes **33**, and is rotatably supported by bearings **38** at the junction of vanes **34**. A rearwardly extending streamlining portion **39** extends from the junction of the vanes **34** back through the tube **36**.

The tube **36** is formed with a forwardly convex portion **41** and a rear straight portion **42**. The propellers **31** and **32** and vanes **33** and **34** are mounted within the straight portion **42**.

Mounted forwardly of the curved portion **41** of tube **36** are a plurality of baffles **44** which are supported by the longitudinal supporting means **35** and are off-set longitudinally of each other so as to direct air through the throat **41** of the tube **36**. The baffles **44** are formed into air-foil-sections such that the air rushing past them and into the throat **41** of the tube will give a forward lift component. A forward component of lift is also developed on the counter vanes **33** and **34**. The dual propellers allow greater thrust to be obtained from the apparatus.

Figure 4 illustrates a power plant of this invention installed in a transonic aircraft of the delta wing type. The delta wing aircraft has a torpedo shaped fuselage **46** which has a triangular wing **47** mounted rearwardly. The rear end of the fuselage is formed into a tube **36** such as shown in Figure 3. The baffles **44** shown in Figure 3 are retained in this configuration but they have been formed to extend outwardly into the wings on the upper and lower surfaces so that more air can be sucked down into the tube **36**. Only one propeler **31** and one set of counter vanes **33** are illustrated in Figure 4, but it is to be understood that any number of propellers and counter vanes may be installed. The baffles **44** extend into the

wing sections and thus draw some of the air from the boundary layer through the tube **36**. This increases the stall resistance and decreases the drag on the wing **47**. To more clearly understand the shape of the baffles illustrated in Figure 4, reference may be had to Figure 6 which is a sectional view taken on a line **6—6** of Figure 4 and illustrates the upper and lower baffles **44** mounted in the fuselage **46** and the wing **47**. The baffles **44** comprise round portions **45** and straight portions **50**. Longitudinal support means **35** are used to support the tube **36** and baffles **44**. It is important to note that the curvature of the baffles **44** must be of the same general shape as the curved portion **41** of the tube **36**. Only this configuration gives a forward lift component L_x from the baffles **44**. This lift component developed on the baffles **44**, the throat **41**, and the counter vanes **33** aids to increase the efficiency of the unit.

An advantage obtained by applicant's power plant not heretofore mentioned is that substantially all torque from the rotating engine **14** and propeller **13** is eliminated by counter vanes **33**. With reference to Figure 2 it is seen that torque developed by the propeller **13** and engine **14** is transferred to the tube **10** through the support means **16**. However, counter vanes **19** intercept the rotating energy of the propeller **13** and exert a torque on the tube **10** which is opposite to the torque developed by the engine **14** and the propeller **13**. In that the torque produced on the vanes **19** is substantially equal to the torque produced by the engine **14** and the propeller **13**, the torque will be eliminated in the tube **10** between the mounting **16** and the vanes **19**, and thus the pilot does not feel any torque. This is a great advantage, especially in aircraft of high wing loading and high power wherein the torque has been known to actually spin the plane about a longitudinal axis. The torque in applicant's invention will be dissipated in torsional stress in the tube. In the embodiment of Figures 3 and 4 the torque is dissipated between the motor supports and the counter vanes.

Although this invention has been described with respect to preferred embodiments thereof it is not to be so limited as changes and modifications may be made therein which are within the full intended scope of the invention as defined by the appended claims.

I claim:

1. An aircraft comprising a fuselage and wings, a trumpet-shaped tube constituting a rear portion of said fuselage, a plurality of baffles forwardly of said tube for supplying air to said tube, said baffles formed so as to be air-foil-shaped in cross-section and with the forward side of said baffles having a greater camber than the rear side, said baffles comprising upper and lower baffles which have semi-circular mid-portions formed in said fuselage and straight end portions adjoining either side of the mid-portions, said baffles defining passages communicating with the exterior of said fuselage and the interior of said tube, a driving means mounted to said fuselage, and a propeller mounted on an output shaft of said driving means within the tube.

2. An aircraft comprising a fuselage and wings, a trumpet-shaped tube constituting a rear portion of said fuselage and supported by longitudinal supports extending to a center portion of said fuselage, the wings of said aircraft connected oppositely to the rear and center portions of said fuselage, a plurality of baffles mounted to said longitudinal supports and extending into the wing on the upper and lower sides, said baffles defining passages communicating with the exterior of said fuselage and the interior of said tube, said baffles air-foil-shaped in section and with the forward side having a greater camber than the rear side so as to draw air into said tube and create a forward lift component, a driving means mounted in said center portion of said fuselage and having an output shaft which extends rearwardly within said tube, a propeller mounted on said shaft within said tube, and a counter vane assembly mounted to said tube behind said propeller to remove the rotational energy imparted to air by said propeller.

3. An aircraft comprising a fuselage and wings, a trumpet-shaped tube constituting the rear portion of said fuselage and supported by longitudinal supports extending to a center portion of the fuselage, the wings of said aircraft connected oppositely to the rear and center portions of said fuselage, a plurality of baffles mounted to said longitudinal supports and extending into the wing on the upper and lower sides thereof, said baffles air-foil-shaped in section and having a center curved portion conforming to the shape of the fuselage and straight end sections received into opposite wings of the aircraft and joining the curved sections, the forward sides of said baffles having a greater camber than the rear sides to draw air into said tube and creating a forward lift component, said baffles defining passages communicating with the exterior of said fuselage and the interior of said tube, a driving means mounted in said fuselage and having an output shaft which extends within said tube, a propeller mounted on said shaft within said tube, and a counter-vane assembly mounted to said tube behind said propeller to remove the rotational energy imparted to the air by said propeller.

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