June 20, 1944. T. H. TROLLER 2,351,645

ADJUSTABLE FAN BLADE CONSTRUCTION

Filed Oct. 17, 1942 3 Sheets-Sheet 1

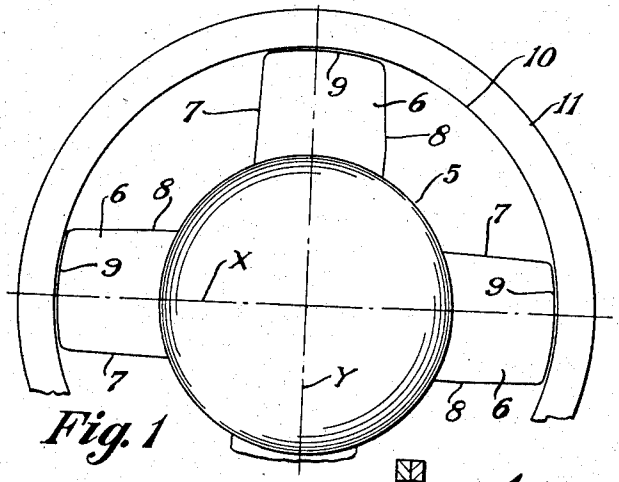


Fig. 1

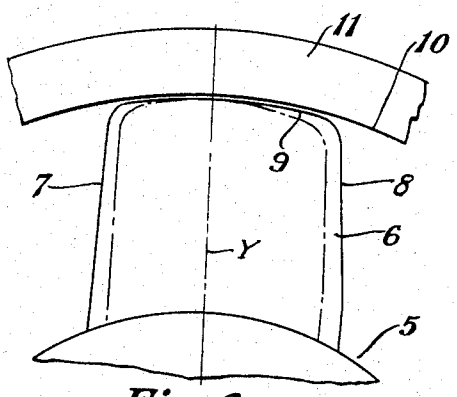


Fig. 2

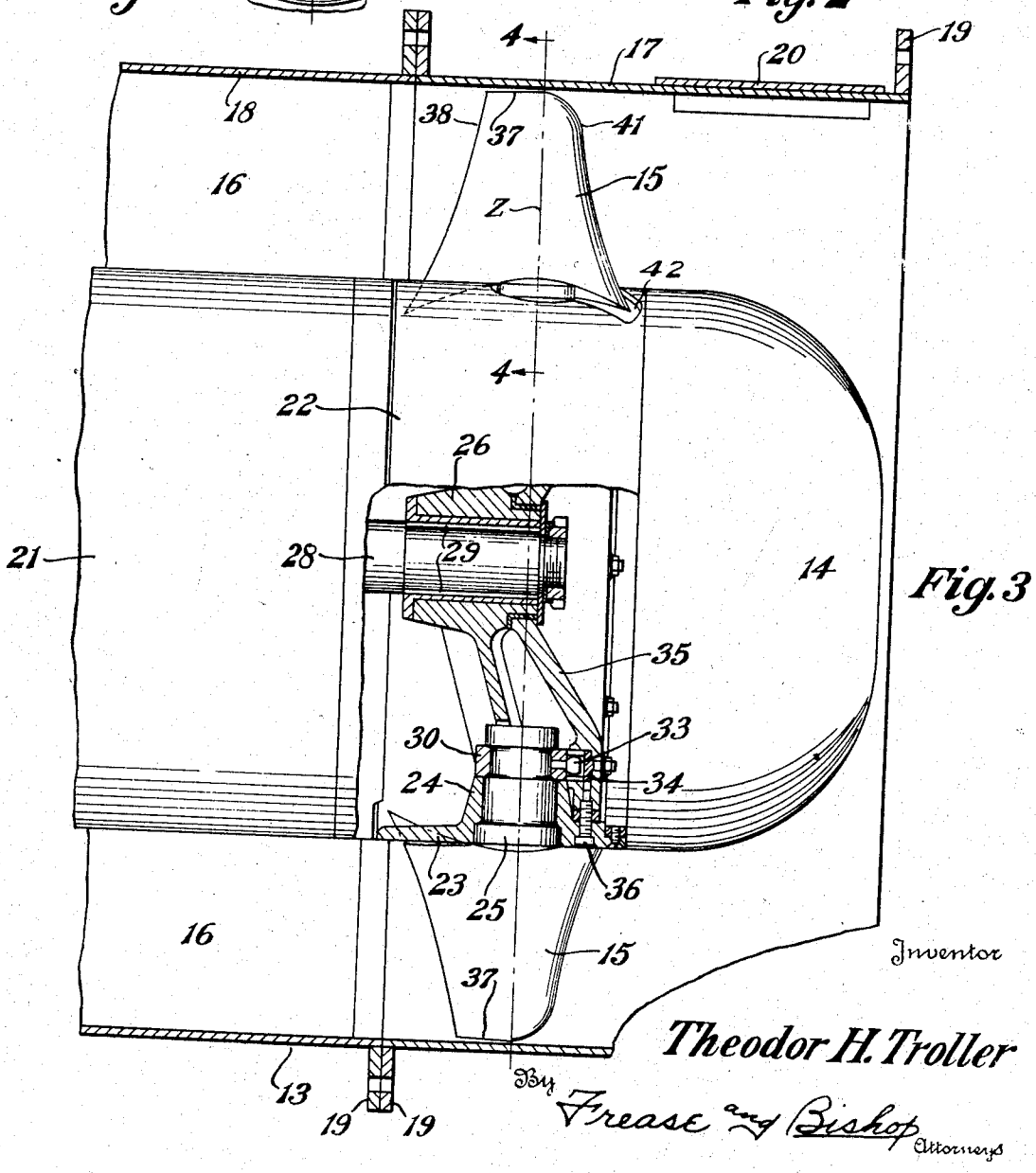


Fig. 3

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ADJUSTABLE FAN BLADE CONSTRUCTION

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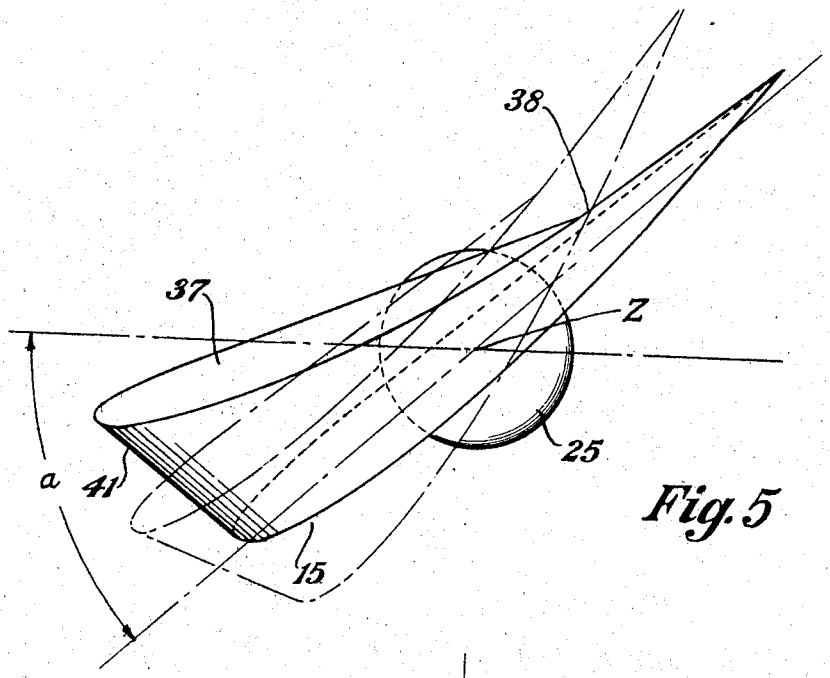


Fig. 5

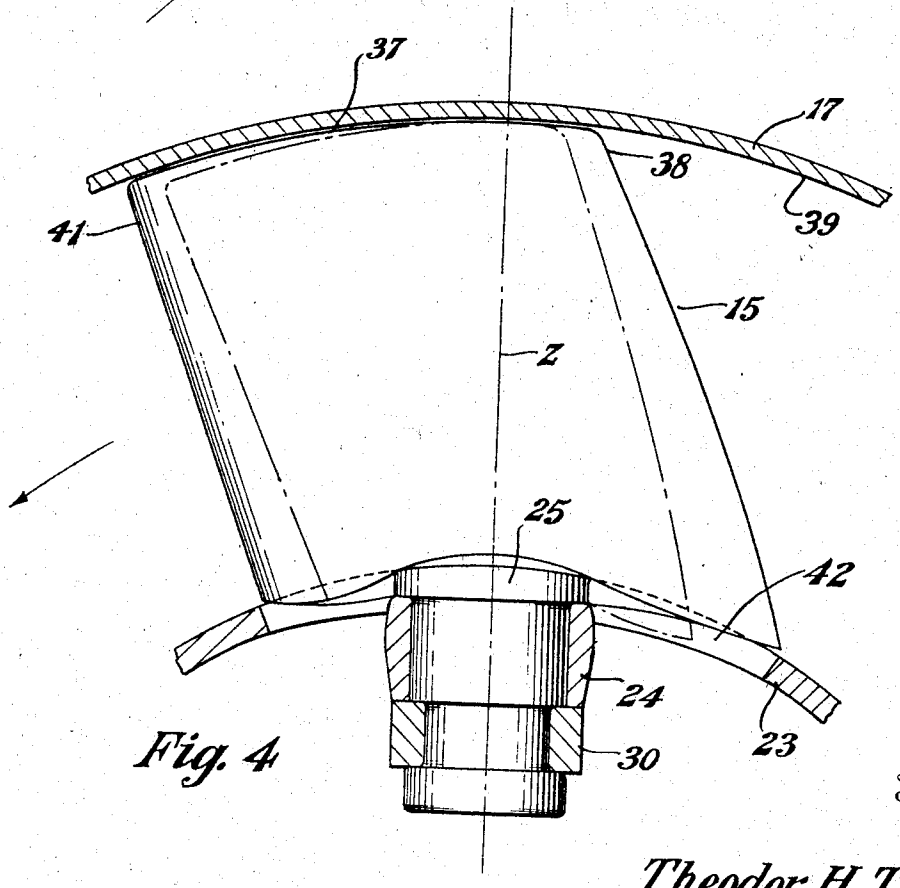


Fig. 4

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ADJUSTABLE FAN BLADE CONSTRUCTION

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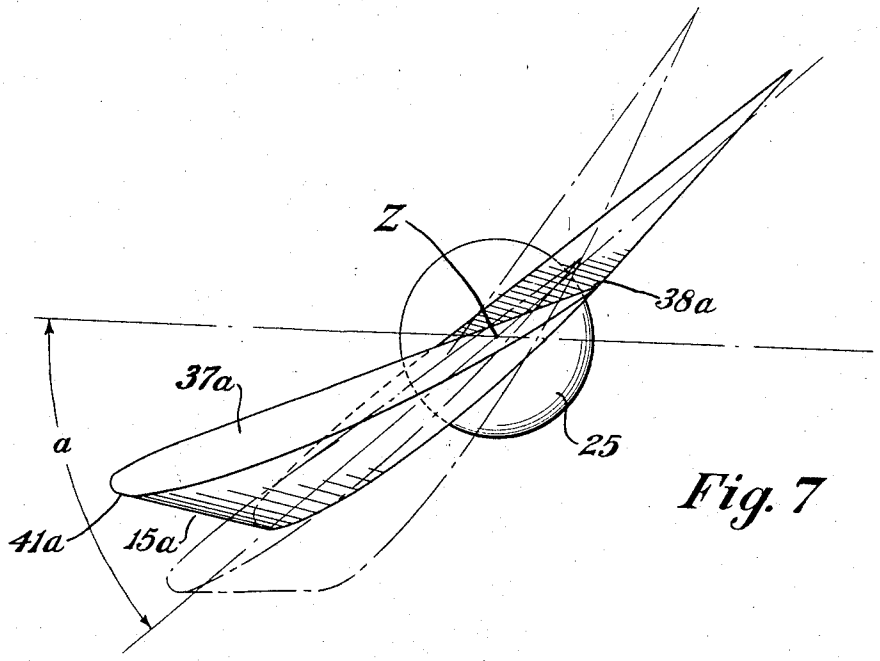


Fig. 7

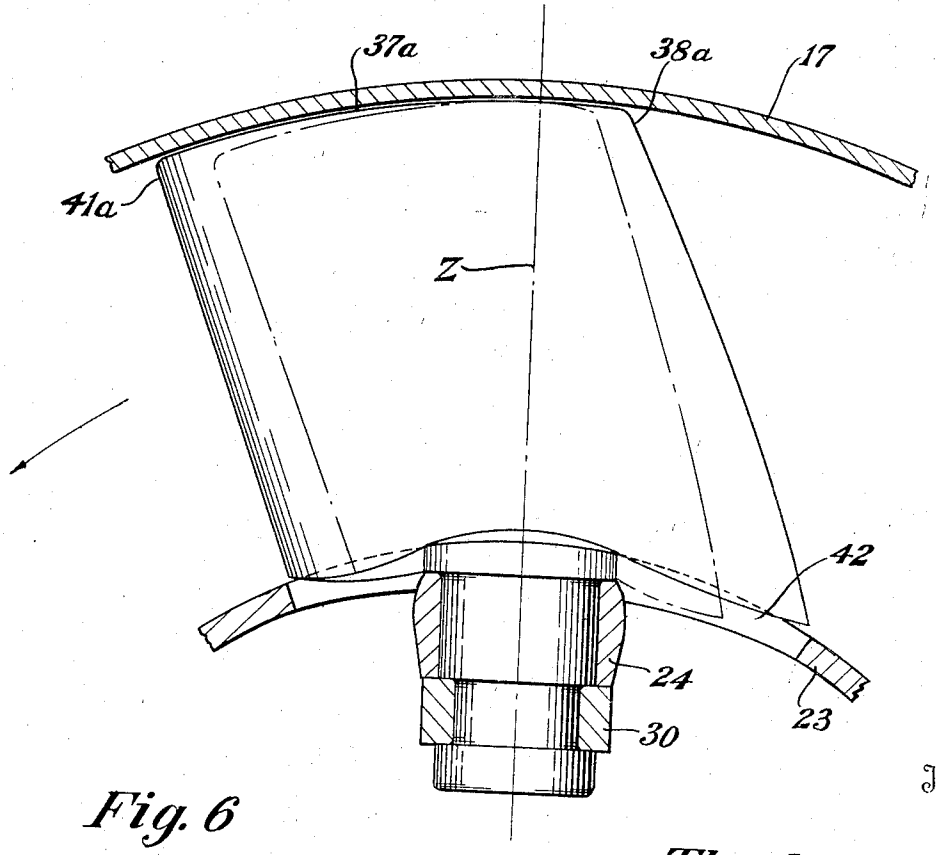


Fig. 6

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UNITED STATES PATENT OFFICE

2,351,645

ADJUSTABLE FAN BLADE CONSTRUCTION

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Application October 17, 1942, Serial No. 462,318

5 Claims. (Cl. 230—114)

The invention relates generally to propellers for moving fluids under pressure through ducts, and more particularly to propeller fans in which the pitch of the blades is adjustable to vary the volume and pressure of the fluid flow.

More specifically, the invention relates to an adjustable blade construction in which the noise level in operation is not adversely affected throughout the range of pitch adjustment.

In propeller fans having adjustable blades it is important to maintain a very small clearance between the blade tip and the outer duct, particularly at the trailing edge of the outer tip. I have found by actual experiment that for a fan of given size having generally a streamlined section with a leading edge portion of a substantial thickness, if the clearance at the trailing edge of the blade tip is increased ever so little due to changing the blade pitch, there is an immediate increase in the noise level of the fan together with a falling off of pressure resulting in decreased output.

In prior propeller fans having adjustable blades the turning axis of each blade extends radially of the propeller hub and intersects the blade tip between its leading and trailing edges and usually somewhat nearer to its leading edge, and the blade tip is curved to provide a uniform clearance with the outer duct at one position of pitch adjustment, namely, at the position wherein the blade is at the lowest angle to a transverse plane normal to the longitudinal axis of the fan.

However, when the pitch of the blade is adjusted to have a greater angle with said transverse plane, the clearance between the leading and trailing edges of the blade tip and the outer duct is increased because the curved blade tip approaches a position along a longitudinal straight line element of the outer duct. In other words, the curved zone on the outer duct immediately adjacent the blade tip is flatter when the pitch of the blade is increased so that while the clearance between the duct and the blade tip at the blade axis remains substantially constant, the clearance at the leading and trailing tip edges increases.

I have discovered that in a fan blade having generally a streamlined section with a leading edge portion of a substantial thickness, it is more important to maintain close clearance between the blade tip at its trailing edge and outer duct than it is to maintain close clearance at other points along the blade tip, in order to avoid substantial disadvantage in respect to noise level and pressure as the pitch of the blade is adjusted.

It is therefore a general object of the present invention to provide an adjustable blade construction having generally a streamlined section with a leading edge portion of a substantial thickness, which will maintain throughout the pitch adjustment range a substantially constant small clearance between the outer duct and the blade tip at its trailing edge.

A more specific object is to maintain this substantially constant small clearance at the trailing edge without too greatly increasing the clearance at the leading edge.

However, the center of gravity of the blade should be kept as nearly as possible in the turning axis of the blade preferably with the turning axis extending through the blade hub and radially of the propeller hub; otherwise in operation centrifugal force will set up excessive bending moments as well as other stresses including torque.

Accordingly, another object is to provide an adjustable propeller blade construction creating a minimum noise level in operation without substantially shifting the center of gravity of the blade from its turning axis.

Another factor which must be considered is maintaining the pitch adjusting mechanism as simple as possible for obvious reasons, and it is therefore a further object of the present invention to provide a novel adjustable propeller blade construction with minimum noise level in operation and with a relatively simple pitch adjusting mechanism.

These and ancillary objects are attained by the improvements, parts, designs, relationships and combinations comprising the present invention, a preferred embodiment of which is disclosed and described herein, said invention being defined in the appended claims.

The invention may be stated generally as including in a propeller fan located within an outer duct, adjustable blades journaled in the fan hub with their centers of gravity located to minimize centrifugal stresses, each of said blades being designed and mounted to provide a uniform close clearance between the blade tip and outer duct at one position of pitch adjustment and substantially the same clearance between the trailing edge portion of the blade tip and the outer duct at other positions of pitch adjustment.

Referring to the accompanying drawings in which a preferred embodiment of the invention is shown by way of example,

Figure 1 is a fragmentatry elevation looking in

at the end of a propeller fan having conventional adjustable blades;

Fig. 2 is an enlarged fragmentary view similar to Fig. 1 showing the clearance between a blade tip and the outer duct;

Fig. 3 is a longitudinal fragmentary sectional view of a propeller fan having a preferred embodiment of the novel adjustable blade construction, part of the fan hub being broken away to show the blade adjusting mechanism;

Fig. 4 is an enlarged fragmentary view as on line 4—4, Fig. 3;

Fig. 5 is a detached plan or radial view of the blade shown in Fig. 4;

Fig. 6 is a view similar to Fig. 4 of another embodiment of the invention in which the design of the fan blade is slightly changed; and

Fig. 7 is a detached plan or radial view of the blade shown in Fig. 6.

Similar numerals refer to similar parts throughout the drawings.

While I have shown a preferred form of my novel adjustable blade construction in the drawings, it will be understood that the invention contemplates variations in the design and mounting of the adjustable blades, as long as such variations are within the scope of the appended claims.

Referring to Figs. 1 and 2 of the drawings the conventional propeller fan indicated generally at 5 has adjustable radially projecting blades 6 journaled in the fan hub on turning axes X and Y coinciding with radii of the fan. These blades 6 are of a conventional type for propeller type fans for moving pressure fluids, and as shown the axes X and Y intersect the tips of the blades at points substantially centrally located with respect to the leading edge 7 and the trailing edge 8 of each blade.

In the position of pitch adjustment of the blades shown in Fig. 1 the tip of each blade 9 forms an arc which provides a small and uniform clearance between the inner surface 10 of the outer duct 11 and the tip of the blade throughout its length. In this position of the blades, which is indicated in full lines in Fig. 2, the blades are at their lowest angle of pitch with respect to a transverse plane, and as the pitch is increased to a greater angle, the blades will assume a position substantially like that shown in dot-dash lines in Fig. 2, in which the clearance between the blade tip and the duct at the Y axis is the same as in the full line position, but the clearance at the leading and trailing edges is considerably increased. This condition is due to the fact that as the angle of the blade is increased the tip approaches a position in line with a longitudinal element of the duct, which element is a straight line, so that the more the angle is increased the greater the clearance will be at the leading and trailing edges of the blade tip.

I have found by actual experiment that with this type of adjustable blade the more the angle of pitch of the blades is increased, the greater is the increase of noise as against that produced by a similar fan of such higher pitch which would have its smallest tip clearance at such a pitch, and also the pressure built up by the fan is lower than that built up by a similar fan having minimum tip clearance at such higher pitch.

In the novel adjustable blade construction shown in Figs. 3, 4 and 5, the fan includes an outer duct or fairing 13 which is preferably cylindrical throughout the portion of the duct surrounding the nose 14, propeller blades 15 and straightener vanes 16. The outer duct is preferably made up of adjoining sheet metal sections as indicated at 17 and 18, which are secured together by suitable means such as flange rings 19 clamped together by bolts (not shown).

If desired, the outer duct may be provided opposite the nose 14 with a door or hatch indicated at 20 which is adapted to be easily removed in a suitable manner for gaining access to the fan hub to adjust the pitch of the blades. The inner fairing preferably includes the nose 14 and a cylindrical housing section 21 which may enclose the motor, and the housing section 21 is preferably supported within the outer duct by means of the straightener vanes 16 which serve to straighten the flow of air from the propeller blades 15. The hub section 22 of the inner fairing in which the propeller blades 15 are mounted is preferably located between the nose 14 of the housing section 21, and its outer surface is cylindrical and conforms to the housing section 21 and the rear part of the nose so as to provide a smooth streamlined air flow along the inner fairing.

The hub section 22 preferably includes an annular rim 23 provided with a plurality of circumferentially spaced sockets 24 in which the shanks 25 of the propeller blades 15 are journaled, and the turning axis of each blade passes through the center line of the shank 25.

Preferably the central portion 26 of the fan hub is keyed on the motor shaft 28 by means of keys 29 in a usual fashion, and the blades 15 are held in their sockets 24 by means of clamping collars 30 engirdling the shanks 25. As shown, the means for adjusting the pitch of all of the blades may include studs projecting from the collars 30 and having rounded heads 33 which are received in sockets 34 provided in an adjusting spider 35 journaled on the fan hub and held in adjusted position by means of screws 36 accessible from the exterior of the hub housing 22 and through the door 20 in the outer duct.

This pitch adjusting mechanism per se forms no part of the present invention, but is described in detail and claimed in the copending application of Charles N. Bebinger Serial No. 449,609, and entitled Pitch adjusting mechanism for propellers; said copending application and present application having the same assignee.

As viewed in Fig. 4 the radius Z of the fan, which passes through the shank 25 and is the turning axis of the blade 15, intersects the tip 37 of the blade at a point relatively close to or adjacent the trailing edge 38. In my invention, the adjustable blades preferably have generally a streamlined section with a leading edge portion of a substantial thickness. As viewed in Fig. 5 the tip of the blade is slightly offset from the axis Z in order to bring the center of gravity of the blade as nearly as possible in the axis Z and still have the Z axis substantially intersecting the blade tip. In other words a compromise is effected between having the Z axis actually intersect the tip and having the center of gravity in the Z axis.

In Figs. 6 and 7, the blade 15*a* is designed so that the Z axis actually passes through the tip 37*a* near its trailing edge 38*a*, in which case the center of gravity of the blade is thrown farther away from the Z axis. Obviously, the blade may be designed so that the tip occupies any location between or approximating the locations shown in Figs. 5 and 7, and in all such variations the Z axis is to be considered as substantially intersecting the tip of a substantially dynamically

balanced blade near its trailing edge, for accomplishing the purposes of the present invention.

In Figs. 3, 4, 5, 6 and 7 the blades **15** and **15***a* are shown at their lowest angle of pitch adjustment, and preferably in this position the tip **37** or **37***a* of each blade, when viewed axially of the fan as in Figs. 4 and 6 is curved to describe an arc which provides a uniform small clearance between the blade tip and the inner surface **39** of the cylindrical outer duct section **17**.

As the blades **15** or **15***a* are adjusted about their turning axes Z from the lowest angle (angle *a*) of pitch adjustment, which position is shown in full lines in Figs. 4, 5, 6 and 7, to a greater angle as shown in dot-dash lines, the clearance between the blade tip and the duct at the Z axis remains constant while the clearance at the leading edge **41** or **41***a* increases materially and the clearance at the trailing edge **38** or **38***a* increases by a very slight amount due to its proximity to the turning axis. The tip clearance in the region of the leading edge portion during adjustment of the blade pitch varies more than the tip clearance in the region of the trailing edge portion whereby the maximum tip clearance occurs substantially where the blade is the thickest.

At the base of each blade **15**, the rim **23** of the hub section **22** is slotted as shown at **42** to allow for adjusting movement of the blade base.

In actual operation, I have found that with this novel adjustable blade construction when the blade pitch is increased to its maximum limit, the noise level and the output of the fan are not substantially adversely affected as compared to these conditions in a fan having blades at the same pitch with a uniform close clearance between the blade tips and the outer duct.

It is apparent that if the blade were so constructed that the turning axis Z would substantially intersect the tip exactly at its trailing edge **38** or **38***a* the clearance between the tip at its trailing edge and the outer duct would be maintained constant for all angles of pitch adjustment of the blade, but in this case the clearance at the leading edge **41** of the tip would be more greatly increased so as to endanger producing too much turbulence in the air stream at those points with a possibility of increasing the noise level because of that condition.

Also, if the Z axis substantially intersects the trailing edge of the blade tip it is more difficult to design a blade having its center of gravity located substantially on or near the turning axis, and if the center of gravity is materially shifted, centrifugal force in operation will set up bending moments, and additional stresses including torque, in the fan.

Accordingly, the turning axis of the blade is preferably located relative to the trailing edge as indicated at Z, in order to accomplish the purposes of keeping the clearance at the trailing edge of the tip as small as possible without introducing too much clearance at the leading edge and without setting up additional stresses in operation to any substantial extent. I have found that in a fan of about 29 inches diameter, that good results are obtained when the turning axis Z substantially intersects the blade tip at a distance of one-half inch to one and one-half inches from its trailing edge.

By constructing the improved adjustable blade so that its shank extends radially of the fan and turning the blade about its shank, the pitch adjusting mechanism may be of maximum simplicity while maintaining the fan substantially in static and dynamic balance.

I claim:

1. Propeller fan construction including an outer substantially cylindrical duct, a fan axially rotatable within said duct and including a hub, blades journaled in the hub, means for turning the blades on their axes for adjusting the blade pitch within predetermined limits, each of said blades having a trailing edge portion and a leading edge portion, said leading edge portion being of substantial thickness, each of said blades having close clearance between the tips thereof and the outer duct during adjustment of the blade pitch between said predetermined limits, the tip clearance in the region of the leading edge portion during adjustment of the blade pitch varying more than the tip clearance in the region of the trailing edge portion whereby the maximum tip clearance occurs substantially where the blade is the thickest.

2. Propeller fan construction including an outer substantially cylindrical duct, a fan axially rotatable within said duct and including a hub, blades journaled in the hub, means for turning the blades on their axes for adjusting the blade pitch within predetermined limits, each of said blades having a trailing edge portion and a leading edge portion, said leading edge portion being of substantial thickness, each of said blades at one position of the pitch adjustment having close minimum clearance between the tips thereof and the outer duct in both the regions of the leading edge portion and of the trailing edge portion, each of said blades at other positions of pitch adjustment having maximum clearance in the region of the leading edge portion and minimum clearance in the trailing edge portion, whereby the maximum tip clearance occurs substantially where the blade is the thickest.

3. Propeller fan construction including an outer duct, a fan axially rotatable within said duct and including a hub, blades journaled in the hub, means for turning the blades on their axes for adjusting the blade pitch within predetermined limits, each of said blades having a trailing edge portion and a leading edge portion, said leading edge portion being of substantial thickness, the turning axis of each blade passing through the region of the trailing edge portion thereof, each of said blades having close clearance between tips thereof and the outer duct during adjustment of the blade pitch between said predetermined limits, the tip clearance in the region of the leading edge portion during adjustment of the blade pitch varying more than the tip clearance in the region of the trailing edge portion whereby the maximum tip clearance occurs substantially where the blade is the thickest.

4. Propeller fan construction including an outer duct, a fan axially rotatable within said duct and including a hub, blades journaled in the hub, means for turning the blades on their axes for adjusting the blade pitch within predetermined limits, each of said blades having a trailing edge portion and a leading edge portion, said leading edge portion being of a substantial thickness, the turning axis of each blade passing through the region of the trailing edge portion thereof, each of said blades at one position of the pitch adjustment having close minimum clearance between the tips thereof and the outer duct in both the regions of the leading edge portion and of the trailing edge portion, each of

said blades at other positions of pitch adjustment having maximum clearance in the region of the leading edge portion and minimum clearance in the trailing edge portion, whereby the maximum tip clearance occurs substantially where the blade is the thickest.

5. Propeller fan construction including an outer duct, a fan axially rotatable within said duct and including a hub, blades journaled in the hub, means for turning the blades on their axes for adjusting the blade pitch within predetermined limits, each of said blades having a trailing edge portion and a leading edge portion, said leading edge portion being of substantial thickness, each of said blades having close clearance between tips thereof and the outer duct during adjustment of the blade pitch between said predetermined limits, the tip clearance in the region of the leading edge portion during adjustment of the blade pitch varying more than the tip clearance in the region of the trailing edge portion whereby the maximum tip clearance occurs substantially where the blade is the thickest, the center of gravity of each blade lying near its turning axis.

THEODOR H. TROLLER.