CHARACTERISTICS OF PROPELLER FANS*

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Propeller fans are generally used in systems where big air quantities are to be conveyed against a comparatively low resistance. This fan is also the oldest type of fan and has the advantage of simple design and low capital cost. However the original design of the propeller fan suffered from a number of drawbacks and the use of it was therefore strictly limited.

With the increased knowledge of aerodynamics in connection with the development of the aeroplane, new machinery for conveying air was constructed and the propeller fan especially was considerably improved, parallel with the design of efficient aeroplane propellers.

In the case of machinery for conveying air, or machines which are moving in air with high velocity, it is essential to keep the resistance against the movement relative to air as low as possible. In pre-war days when little was known about the character of air resistance in general, this point was not considered, but as the speed of aeroplanes were gradually increased this important detail attracted more and more interest. To signify a body or a design with low resistance against air movement, the word "streamline" has been coined; an expression which to the general public usually conveys a smooth and curved design, but which in reality represents mathematically defined shapes and forms where the least deviation from the correct design often means considerably increased air resistance and loss of power. It is difficult to explain the idea without resorting to mathematical formulas and complicated diagrams, but with regard to propeller fans a simple comparison can be made with the losses that occur in bearings of different designs.

While in the old type of fan the major portion of the losses were caused by the air sliding against the propeller blades, the losses in the modern fan which are very small in comparison are created by

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the air "rolling off" the blades. The losses in the two cases stand in the same relation to each other as the friction in a plain bearing to the friction in a ball or roller-bearing.

From what has been said above, it is obvious that the difference between the design of the old type of propeller fan and the new one is that this latter has an accurate geometrical shape with blades in exact positions and with mathematically defined pitch. For this reason the aeroplane fan is made of diecast material, usually silumin or any other aluminium alloy with low specific gravity, while the old type has blades of sheet metal or cardoid shaped cast iron blades. The light material used in modern fans makes for a low momentum of inertia and consequently low-starting torque.

The fan hub is another source of loss and in the modern design the hub is usually extended on both sides with caps of streamline design. Some fans have one cap on each side but in most cases only one cap is fitted on the pressure side. The cap on the suction side is of less importance and adds in reality very little to the efficiency.

In Figs. 1 and 2 the principal design of the two types are shown. The designs do not refer to any particular make. In practice their appearance vary considerably, both with regard to the number of blades and the shape of the blades, but while this mainly applies to the old type, the streamline types available on the market may be divided only into two groups of different type of pitch of the blades. However, there is very little difference in performance between streamline fans of different makes and the same applies to fans of the old type although they show a greater variation in performance.

Propeller fans are of importance in connection with withering schemes for which they are particularly suitable and it is therefore of interest to study their characteristics from this point of view. Makers frequently do not give full information with regard to their fans and for this reason a test was carried out on two fans representing the two types, both of British manufacture.

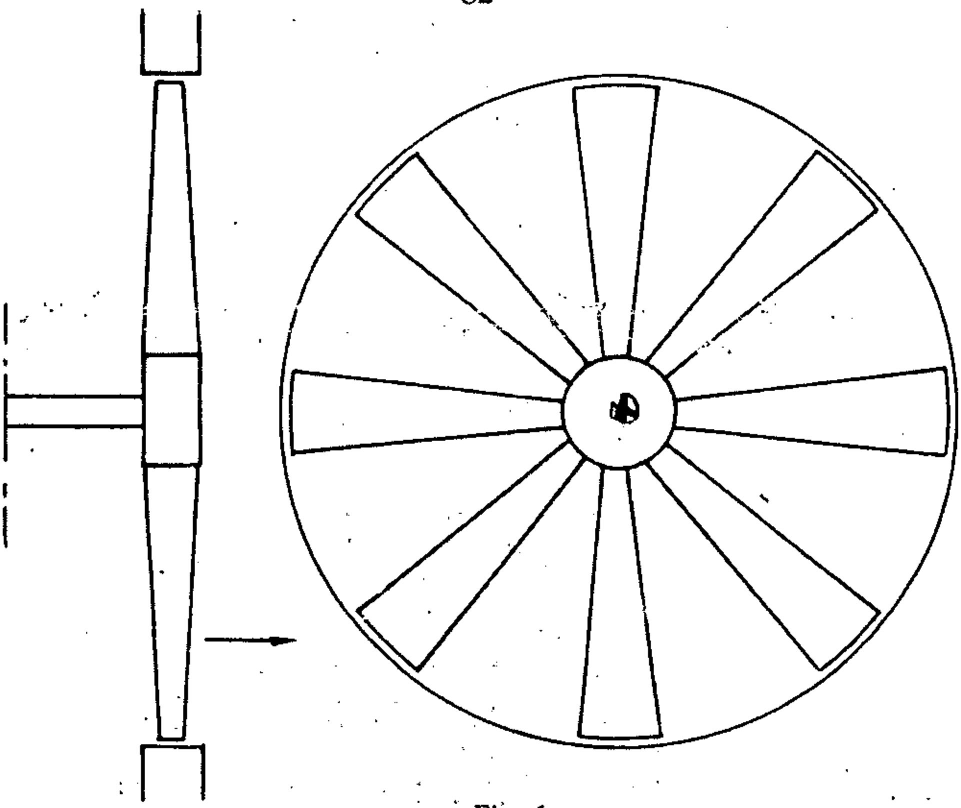

Fig. 1
Design of Propeller Fan of Old Type

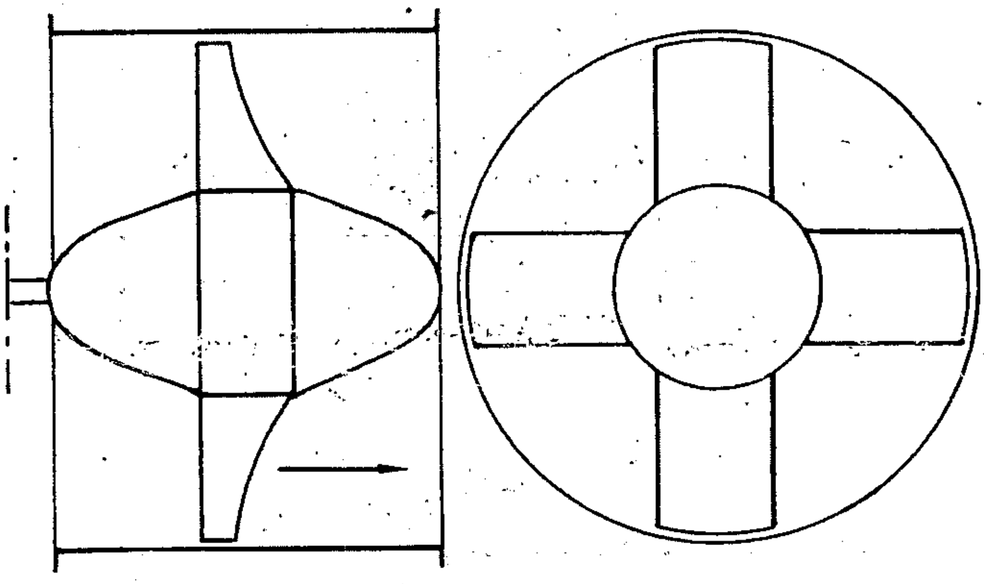

Fig. 2
Design of Aeroplane Propeller Fan

The fans were mounted, one on each side of an air-conditioning chamber of the ordinary design, 12 ft. wide, 30 ft. long and 24 ft. high approximately. The chamber was divided into two portions by means of a streamline-shaped partition in the centre, and each fan thus worked independently of the other but under identical conditions. The fans were of slightly different size, the old type having a diameter of 7 ft. and the aeroplane fan slightly less than 6 ft. They were further run at speeds of 350 and 400 r.p.m. approximately and were chosen to deliver about 45,000 cu. ft. per minute against a resistance of 10 mm. water gauge total pressure at highest possible efficiency. On the sides of the chamber were fitted a number of swivel doors each one foot wide, which when fully opened acted as guides for the air and which could be closed airtight. Both fans were driven by electric motors and Vee rope belt.

At the top of the chamber was finally fitted a vertical cylindrical duct which by means of a two-way valve could be put into communication with either of the two portions and through which the air could be expelled. The reason for this latter addition was to provide a duct where exact measurements could be taken on air volumes and pressures with the aid of a Pitot tube and precision water gauge.

The curves shown in Fig. 3 are drawn from the results of these measurements. Each curve is based on four readings at different resistances created by partially closing the test duct. In each case fifty measurements were taken with the Pitot tube geometrically distributed over the section of the circular duct and the average was plotted in the diagram. In the case of the old type fan pendling occurred at pressures over 10 mm. and it was very difficult to obtain exact results. Two curves are therefore shown between which the observed data lie.

The curves are marked with letters N, P and Y denominating horse power, total pressure and efficiency, respectively. The letters are further indexed with A and O referring to aeroplane and old type fan. The curves for the aeroplane fan are fully drawn, while the others are shown in dotted lines.

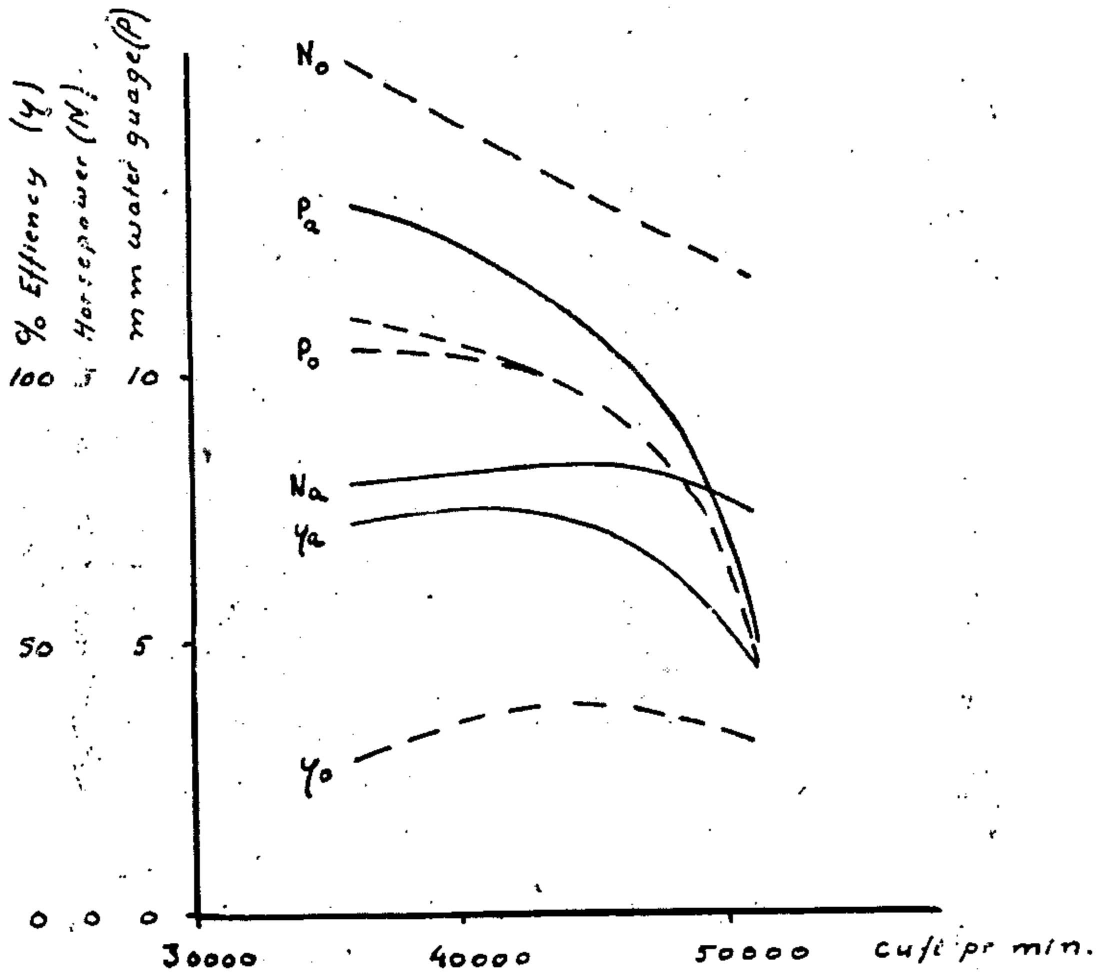
% Effiency (η)
Horsepower (N)
mm water guage (P)
100
10
50
5
0
0
0
30000
40000
50000
cu/ft pr min.
No
Pa
Po
Na
ηa
ηo

Fig. 3.

In comparing the curves the most striking difference is shown with regard to efficiency and power consumption. While the aeroplane fan has a mechanical efficiency of about 70 per cent at 45,000 cu. ft. a minute, the old type fan reaches only 37 per cent which also is the highest efficiency reached by that fan. On the other hand the efficiency of the aeroplane fan drops faster towards low resistances which naturally is a drawback.

In this connection it may be of interest to define what is meant by efficiency. A fan conveys a certain air volume against a certain pressure. The product of the pressure and the air volume represents the mechanical work done by the fan, which compared with the consumption of power on the fan shaft gives the efficiency in per cent. With regard to the pressure this is the sum of the static and dynamic pressures, the former representing approximately the resistance against air movement in the system, and the latter being a function of the air velocity and proportional to the square of this.

The power consumption for the aeroplane fan varies throughout the range tested between 3·7 and 4·1 h.p. which is a negligible variation, while the power consumption for the other fan steadily increases from 5·9 to 8 h.p. at 13 mm. total pressure. With this type of fan there is, therefore, the risk that the motor may be overloaded if the fan is working against high pressures.

The two pressure curves show the same characteristics apart from the pendling referred to above. The flatter this curve is the more sensitive is the fan to variations in pressure. This means that for a certain increase in pressure the fan with the flat curve will lose in capacity more than the fan with the steep curve. This is a point of particular interest in withering. If, for instance, in an ordinary withering scheme only one half loft is running, a considerable resistance is created, particularly as in most schemes the two fans are connected together and cannot be run separately. The capacity drops unduly with a corresponding increase in power consumption and risk of overloading.

With the aid of the characteristics shown in Fig. 3., it is now possible to determine the conditions in the loft, and particularly the resistance created by the tats and the leaf. This can be done by running the fans in the normal way for withering and at the same time measuring the power consumption and air volume with the aid of an anemometer. With these data one can find from the characteristics the corresponding total pressure and, with the knowledge of the air velocities, approximately estimate the resistance of the tats. As the tests in the first instance only aimed at a comparison between the two types of fans, sufficient data are not available at this stage to warrant any conclusions with regard to total resistance. It is, however, hoped that the tests will be continued and the resistance of different type of tats and bulking chambers will be measured.

From the characteristics it is obvious that the aeroplane propeller fan is far superior to the old type of fan. It has, however, a drawback and that is a considerably higher cost which is only natural and due to the exact design and workmanship embodied in manufacturing. It is difficult to give any relative figures, especially as prices vary, but with regard to the two fans which were tested the aeroplane fan cost approximately two-and-a-half times as much as the other. This difference in price should however be considered in conjunction with the saving in power. The aeroplane fan consumes approximately 3 units less than the other fan or very nearly 50 per cent. less. With a running time of 1,000 hours per annum and a power price of 6 cents a unit, this represents Rs. 180 per annum which capitalised at 10 per cent. is Rs. 1,800—a sum more than sufficient to cover the difference in price.

In the case of oil engine drives the saving may not be so large but there is another point to consider. If a factory driven by an engine contemplates an increase in the capacity of the withering scheme by installing additional fans, it is often found that with the old type the power available is not sufficient, and under those circumstances there is the question of installing either additional engine power or more efficient fans. In most cases the efficient fans should be the cheapest of the two alternatives.

A number of firms in Great Britain now manufacture fans of the aeroplane propeller type, but they have only in a few cases been used for withering mainly because of their higher price. With the introduction of electricity one may however expect a wider use, particularly as then economy of power becomes of greater importance.