May 28, 1968 W. A. OMOHUNDRO 3,385,516

FAN CONSTRUCTION

Filed March 31, 1966 2 Sheets-Sheet 1

Fig. 1.

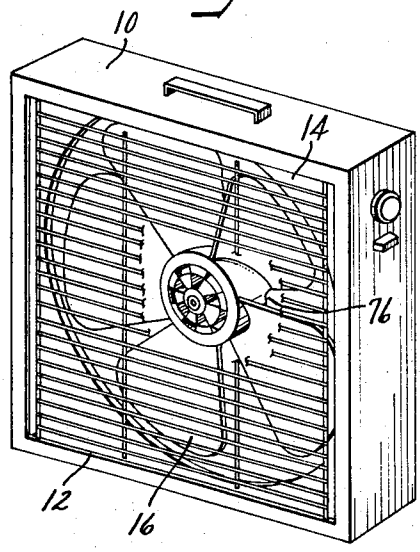


Fig. 2.

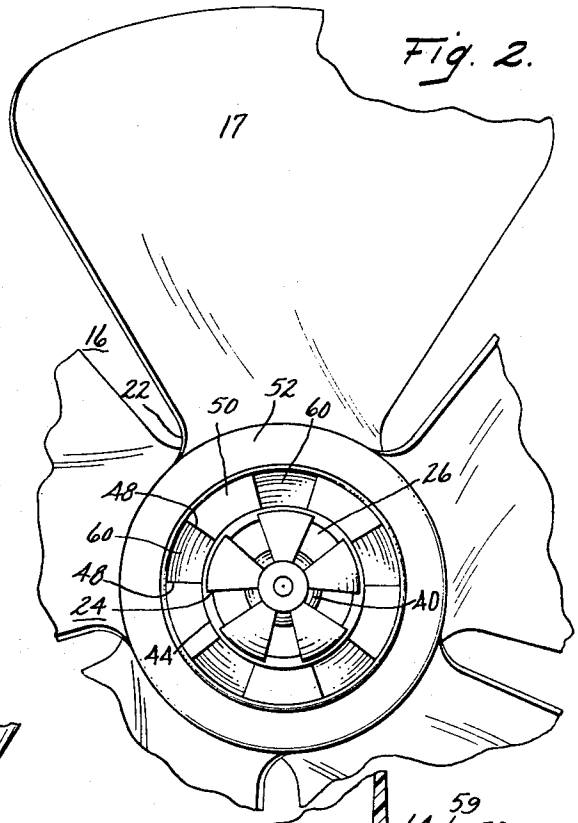


Fig. 3.

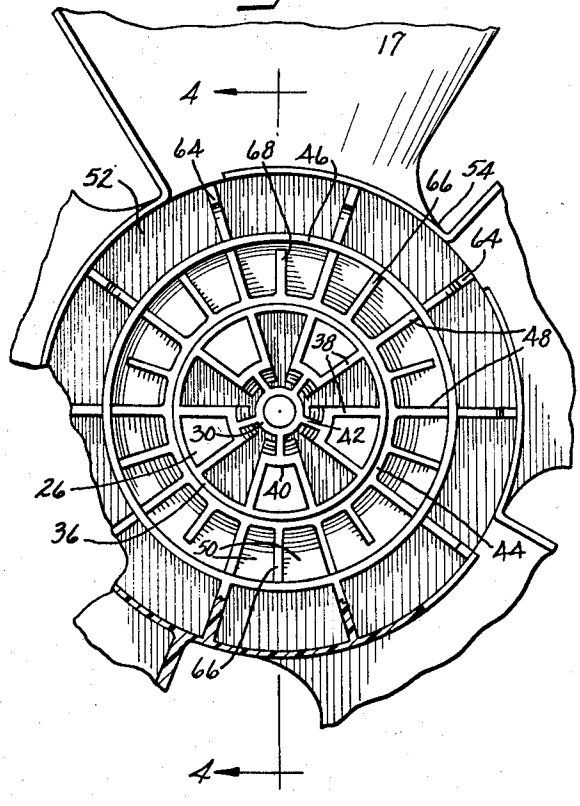
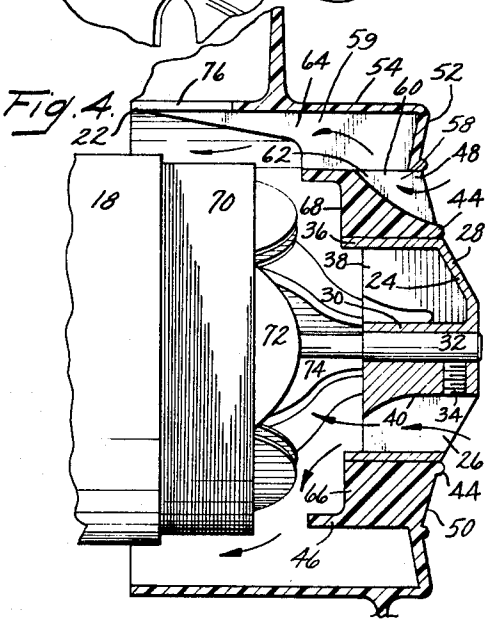


Fig. 4.



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May 28, 1968 W. A. OMOHUNDRO 3,385,516

FAN CONSTRUCTION

Filed March 31, 1966 2 Sheets-Sheet 2

Fig. 5.

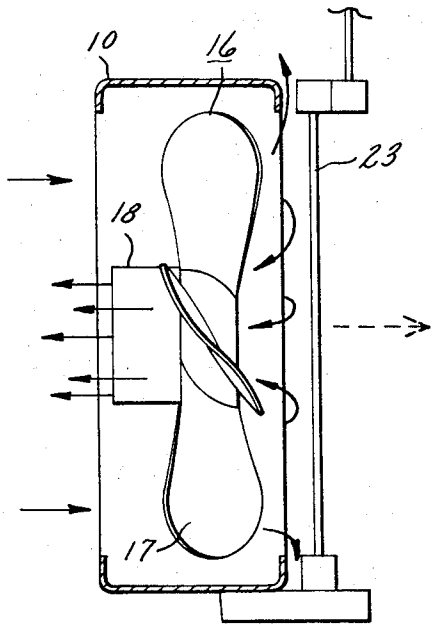


Fig. 6.

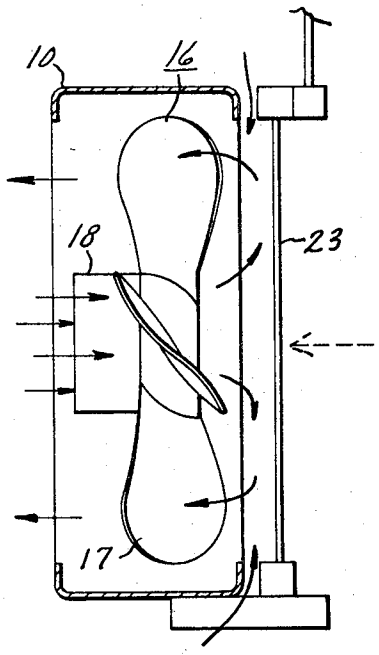


Fig. 7.

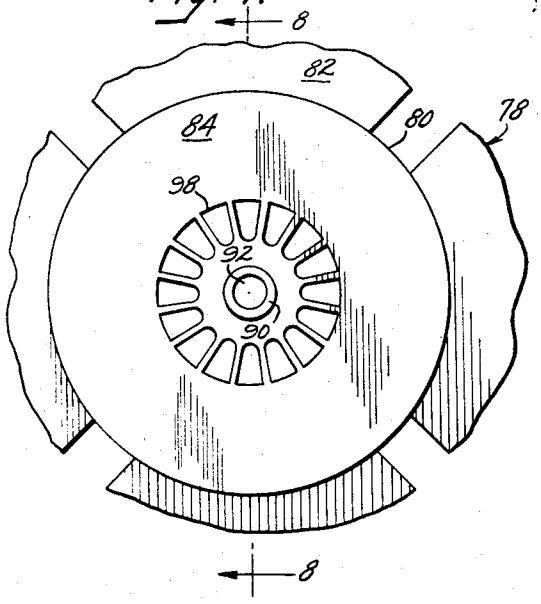
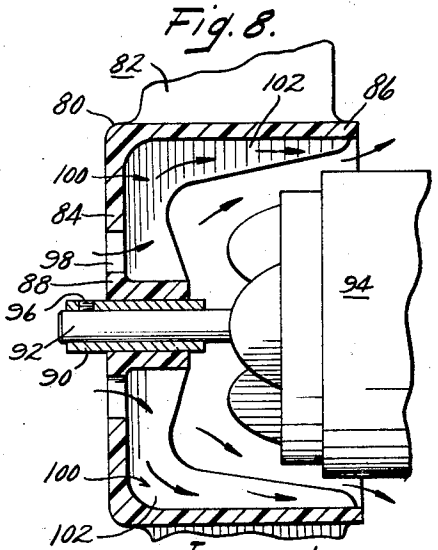


Fig. 8.



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3,385,516

FAN CONSTRUCTION

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6 Claims. (Cl. 230—259)

ABSTRACT OF THE DISCLOSURE

A reversible electric fan having a fan blade and hub construction molded from a plastic composition which softens and hence may deform at temperatures only slightly higher than normal operating range. Cooling passages are formed in the hub to direct cooling air over the plastic hub parts even with air flow blocked and upon either direction of rotation.

This invention relates to electric fans and more particularly to an improved fan blade and hub construction.

While the invention described herein is not limited to a particular size fan, it is particularly useful and advantageous in connection with the so-called "twenty inch" fans which are manufactured in large volume and primarily sold to individuals for use in private dwellings. In view of the highly competitive nature of this business, it is extremely important that the fan be constructed as inexpensively as possible while yet providing the efficiency and reliability required. An improvement in just one component frequently results in compounded savings. For example, if a fan blade can be made more compact and with less material, savings are not only realized from reduced material costs of the fan proper, but a smaller, lighter and less costly motor and fan casing may be employed. This, in turn, results in reduced packaging and transportation costs. Naturally, a lighter fan is also more convenient for the consumer to handle.

Substantial weight reduction can be obtained by utilizing plastic or similar lightweight materials for the fan blade as opposed to using metal such as steel. On difficulty encountered in using fan blades made of low cost plastic material is that the material is not sufficiently strong and heat resistant to withstand abnormal operating situations to which it may be subjected by the user. For example, the "twenty inch" fan is most often positioned adjacent a window frame for operation, and it is not uncommon for a user to inadvertently energize the motor when the window is closed. This obstruction to the air flow will cause the motor to be overloaded, with a resulting heat rise. Unless special provision is made to protect the fan blade from such heat, a blade of low cost plastic will distort and fail. It is therefore desirable that the plastic blade be able to satisfactorily withstand such abnormal condition.

In view of the foregoing, it is a primary object of this invention to provide a fan having an improved low cost plastic blade construction which can withstand the extra heat generated by the fan motor when the air flow of the fan is obstructed.

It is another object of this invention to provide an improved low cost plastic fan blade which restricts the heat flow from the fan motor to the blade and has provision in its hub portion for permitting air flow therethrough.

It is a further object of this invention to provide an improved low cost electric fan having a light weight plastic blade construction which has a minimum of axial depth and a high air output.

In accordance with one aspect of this invention, there is provided a fan blade made of plastic which will deform when subjected to normal fan operating forces at temperatures somewhat above normal operation. The

blade is provided with a plurality of blade elements extending outwardly from a central hub and is rotated by a motor drivingly connected to the hub and partially position within the hub. The hub is formed with a series of air passages for permitting air flow through the hub to prevent a heat build up by the motor which would cause the plastic blade to soften and fail and possibly cause motor failure. With such construction, plastic materials may be employed for the fan blade, thus providing a low cost unit which is also lighter and hence easier for the user to handle.

To obtain a given air flow with a plastic fan blade, it has been found that five blade elements is the optimum in that the axial depth of the elements can be made smaller than when using fewer elements. Smaller elements, of course, require less plastic to retain their shape, hence lower cost and lighter weight. Also, with the reduced axial depth, a shallower casing can be used to enclose the unit resulting in further savings in weight and cost.

Further features, objects and advantages will become apparent with reference to the following written description and drawing in which:

FIG. 1 is a perspective view of a portable twenty inch electric fan;

FIG. 2 is a front elevational, partially cut-away view of the fan;

FIG. 3 is a rear perspective view of the blade hub of FIG. 2;

FIG. 4 is a cross-sectional view of the fan blade along the line of 4—4 of FIG. 3 and including a side view of a portion of the motor;

FIG. 5 is a schematic view of a fan in operation during "closed window" situation;

FIG. 6 shows the fan of FIG. 5 operating in the reverse direction;

FIG. 7 is a front elevational, partially cut-away view of an electric fan having a modified form of fan blade hub; and

FIG. 8 is a partial cross-sectional view taken substantially along the line 8—8 of FIG. 7.

Referring now to the drawings, there is shown in FIG. 1 a "twenty inch" electrical household fan having an external rectangular casing **10**, a grille **12**, an orifice plate **14**, a fan blade **16** driven by a motor **18**, and a switch **20** for controlling energization of the motor. The fan blade **16** includes a central somewhat cup-shaped or cylindrical hub **22** and five blade elements **17** formed integrally wth the hub and extending radially outwardly therefrom.

In accordance with the invention, it is desirable that the fan blade **16** be formed of plastic or other similar lightweight material so that the blade can be molded as a one-piece integral unit. While various plastic materials may be employed, good results with reasonable cost have been obtained from a plastic known as acrylonitrile butadiene styrene, commonly referred to as ABS. Although such material has many desirable characteristics, one of its disadvantages is that when used in a fan blade, it can only withstand temperatures on the order of 180° F. before it will become somewhat distorted while under the stresses of fan operation. Another suitable material is polypropylene which while not as strong as ABS at low temperatures, can withstand fan stresses better than ABS at temperatures on the order of 270° F.

It has been found that during normal operating conditions a fan blade made of either of the above-mentioned low cost plastics can adequately withstand the heat generated by the motor when subjected to normal operating stresses. However, a commercially successful fan should be able to satisfy safety and performance requirements even under an abnormal operating condition if such condition is likely to occur.

As mentioned above, quite often fan users operate a twenty inch fan near a window and the fan is occasionally inadvertently energized while the window is closed. Under such conditions, the air flow generated by the fan is naturally severely restricted and the motor is overloaded causing increased heat generation. It has been found that unless this heat is dissipated, the temperature to which the plastic blade is subjected is quickly raised above 300° F. Such temperature will rapidly distort low cost plastics of the type previously mentioned, particularly when under operational stresses.

In accordance with the invention, to overcome this problem and to make the use of low cost plastics possible, air passages have been formed in one end of the hub **22**. It has been found that when a fan without passages in the hub is operating adjacent a closed window, a large pressure differential is built up between the front and back of the fan. With no release, this causes the motor to heat; and with the restricted air movement, the heat is not dissipated. By introducing air passages, the air has an escape and the resulting air movement through the hub in and over the motor cools these components. The result is that the plastic hub does not reach its distortion point and does not fail.

Incidentally, it should be noted that the direction of air flow through the hub in the "closed window" situation is dependent on the direction the fan is rotating. When the fan is directing air toward the closed window **23** as shown schematically in FIG. 5, air is forced through the hub apertures and in and around the motor. When air is directed by the fan away from the closed window as in FIG. 6, air is drawn over the motor and through the hub apertures.

With certain plastics, the entire fan blade including the air moving elements and the hub may be formed as a single plastic unit. However, to further improve the heat withstanding characteristics of the arrangement, a metal insert may be positioned within one end of the hub to contact the motor shaft. The insert dissipates the heat from the motor shaft so that the temperature at the insert and plastic interface does not rise to a level to cause distortion of the plastic. As can be seen from the drawings, and particularly FIG. 4, an insert **24** has been utilized in the arrangement shown. The insert **24** may be connected to the hub in any suitable fashion.

With regard to the "closed window" situation, the particular shape of the air passages in the hub is not critical. However, it is also desirable that some cooling effect for the blade be provided during normal operation.

The fan element of the invention as shown in FIGS. 2–4, includes an inner annular series of alternately spaced passages **26** and solid sections **28** within the insert. Since each of the passages **26** and solid sections **28** within the inner annular series are substantially identical, only some are indicated by numerals in FIGS. 2 and 3 to simplify the appearance of the drawing. Considering the insert **24** in greater detail, it can be seen that there is included a cylindrical shaft receiving portion **30** adapted to fit over shaft **32** of motor **18**. The insert may be secured to the shaft **32** by a suitable set screw threaded into radially extending opening **34** formed in the cylindrical portion **30** and one sector of the insert. In this connection, it should be noted that the insert has somewhat of a frusto-conical cross-section on one end thereof, as can be seen in FIG. 4. Thus the opening **34** is easily accessible with a screw driver through entry to one of the passages **26**.

The insert further includes an annular wall **36** concentrically spaced from the inner cylindrical portion **30** and connected thereto by a plurality of radially extending walls **38**. The solid sections **28** extend between alternate pairs of the radial walls **38**. As can be seen from FIGS. 2 and 3, each of the solid sections **28** has the shape of a section of a circle having its inner tip or apex removed; or in other words, it may be said to have the shape of a truncated sector.

The air passages **26** also have a cross-section with the shape of a truncated sector when viewed from the air inlet side of the insert, as in FIG. 2. The entry to each of the passages is defined by a pair of the radial walls **38** and by the annular wall **36** and the outer wall of the cylindrical portion **30**. With such an arrangement, the air during normal operation enters the air passages **26** in substantially an axial direction. However, each of the passages **26** is further provided with a curved wall or vane **40** which slopes rearwardly and radially outwardly from the righthand end or front of the insert as viewed in FIG. 4. The curved walls or vanes **40** cause the series of passages to serve as a miniature centrifugal type fan in that the air is drawn in through the right end of the passages, as viewed in FIG. 4, and is directed in a combined axially and radially outward manner. It should be noted that during normal operation the air flows through the insert passages in this fashion regardless of which direction the fan blade is rotated.

To improve the structural strength of the assembly, there is provided a plurality of radially extending ribs **42** which connect the radially inner surface of vanes **40** to the inner cylindrical section **30**. It should be understood that the insert is actually a skeletonized structure in that it is basically hollow except for the ribs and walls which have been mentioned. Such a unique arrangement requires a minimum amount of material but yet provides the necessary structural strength. Moreover the walls and ribs have been so designed that the insert can be easily molded.

Turning now to the remainder of the hub construction, an annular wall **44** surrounds wall **36** of the insert **24**. These two walls may be formed as a single wall if the entire hub is molded as one piece. Another annular wall **46**, which has an axial dimension greater than that of the axial dimension of wall **44**, is concentrically spaced from wall **44**. A plurality of radially extending walls **48** are equally spaced within the annular section defined by walls **44** and **46**. These walls **48** have an axial dimension approximately equal to that of wall **44** and are radially aligned with walls **38** within the insert **24**.

A plurality of solid sections **50** extend between alternate pairs of walls **48** and between annular walls **44** and **46**. Surrounding these solid sections **50** and the right end of wall **46**, as viewed in FIG. 4, is an annular wall **52**, which is, in turn, connected to cylindrical portion **54** of the hub. Between each pair of solid sections **50** there is formed an air inlet defined by alternate pairs of walls **48** and by the right end of annular wall **44** and the inner edge of annular wall **52**. These inlets mark the entry to a plurality of air passages **58** defined by alternate pairs of walls **48** and by a plurality of curved walls or vanes **60**. As can be seen from FIG. 4, the vanes **60** extend from the right or outer end of wall **44** to a point on wall **46** which is approximately radially aligned with the left end of wall **44**. The portions of the vanes **60** which combine with wall **46** define air outlets **62** from air passages **58** together with alternate pairs of walls **48** and with the inner edge of wall **52**; or in other words, there is formed a plurality of air outlets **62** in annular wall **46** at locations which are equally spaced around the hub between alternate pairs of walls **48**.

Outlets **62** lead into hollow areas or passages **59** defined by the axially inner face of wall **52**, by the radial inner surface of cylindrical portion **54** and by alternate pairs of radially extending walls **64** which extend between wall **46** and cylindrical portion **54**. As can be seen in FIG. 4, the walls **64** taper axially toward the left end of cylindrical portion **54** to provide structural strength to the hub. From FIG. 3 it can be seen that radial walls **64** are radially aligned with wall **48** and **38**. As can be seen by the arrows in FIG. 4, the air passages **58** and **59** function to draw air through the hub and around the motor **18** by a centrifugal fan action in approximately the same manner as the air passages within the insert **24**. Thus, the air enters in an axial direction and is ducted axially and radially out-

wardly through passages 58 before being once more directed axially by the walls of passages 59.

To provide additional structural strength to the hub, there is formed a series of radially extending ribs 66 integrally formed with the back or motor side of sections 50 and extending between walls 44 and 46, as seen in FIG. 3. Similarly, on the back or motor side of vanes 60 there is formed a series of radially extending ribs 68 which extend outwardly from annular wall 44 and terminate slightly before reaching wall 46.

Now that the overall construction has been described in detail, the operation of the hub and insert can be more easily appreciated. Both series of air passages 26 and 58, 59 serve as centrifugal air moving devices during normal operation which draw air through the hub to cool the plastic blade. The inner series of passages 26 are primarily designed to cool the inner section of the hub, whereas the other series of passages 58 are primarily designed to cool the outer portions of the hub. The auxiliary fins 74 formed integral with the rotor also cause air circulation to cool the adjacent components. Motor cooling is also provided by the series of ribs 64 as they circulate air around the motor.

Note that the inner series of passages 26 are circumferentially off-set from the outer series of passages; or in other words, each inner passage 26 is radially aligned with an outer solid section 50, and each inner solid section 28 is radially aligned with an outer air passage 58. Such an arrangement provides uniform air distribution and at the same time contributes to the overall strength of the construction. It should also be noted that although there are a considerable number of different walls and ribs employed in the design, they are positioned so as to facilitate a molding operation, and to provide maximum strength with a minimum of material.

As has been mentioned, the entire fan blade and hub construction can be made as a single integral unit or if the materials employed cannot withstand abnormal heat conditions, the central portion of the hub may be formed as a separate insert. The primary purpose of the insert is of course to prevent excessive heat from reaching the more easily deformed plastic material of which the remainder of the blade is formed. However, this can be accomplished in more than one way. By making the insert of a material which is a good heat conductor, such as most metals, and providing the insert with air cooling passages, heat from the motor can be dissipated to the air so that the temperature of the hub portions surrounding the insert is kept below a desired level. Also, due to the larger diameter of the insert, the heat density of the outer surface of the insert is reduced from that of the shaft.

Alternatively, the insert may be formed of a material which is a poor heat conductor, with the idea being that the heat from the motor transmitted through the shaft is blocked by the insert from being conducted to the surrounding hub. In effect, the heat is confined to the motor and its shaft. By the use of the cooling air passages, this heat may be removed from the motor to keep its temperature below a desired level.

As explained, the hub construction described permits the use of lightweight, low cost plastics for fabricating the blade. This advantage is maximized when a minimum amount of material is employed. In accordance with the present invention, the blade is provided with five individual elements in that it has been found that this number of elements requires the least amount of material for a given air output of a twenty inch fan. Some of the reasons for this are that with five elements, each individual blade moves less air and is under less stress than each element in a blade having a fewer number of elements so that the thickness of each element can be minimized. In the present instance, excellent results have been obtained by tapering the element thickness from .10 inch at the end of the element connected to the hub to .05 inch at its outer tip.

With such relatively thin plastic blade elements, it is very important that the stresses on the elements be minimized. When a blade is rotated, the centrifugal forces produced are radially directed on lines perpendicular to the rotational axis. Hence, it is desirable that the blade elements be formed with the surfaces aligned with these expected centrifugal forces. To obtain efficient fan operation, it is also desirable that the blade element surfaces be twisted rather than planar. In accordance with the invention, a preferred shape is the so-called "helical" blade element which is generated by a radial line perpendicular to the rotational axis moving on the hub surface in a slightly curved path. Such a blade element shape is aligned with the centrifugal forces.

Further, when utilizing five blades as opposed to a lesser number of blades, the pitch or axial dimension of the blade is less, so that the hub is axially shorter and the individual elements are axially shorter, thus further reducing the amount of material required. In the twenty inch fan blade illustrated, the axial dimension of wall 58 is less than three inches. To further reduce the overall axial dimension of the fan, the rotor fins 74 are formed with outer edges curved to complement the cup-shape of the hub 22. This permits more of the motor to fit within the hub. This increased compactness also helps to reduce packing and shipping expenses.

Another advantage of utilizing a blade with a minimum of axial depth is that it is particularly suited for use with an electrically reversible fan in that the orifice plate 14 can be centrally positioned with respect to the blade and substantially the same output can be obtained from the fan when rotated in either direction. Utilizing more than five blade elements in a blade of the type herein described decreases efficiency to an undesirable level and also increases noise problems. Thus from an overall viewpoint, outstanding performance is obtained with a five element blade having the characteristics described.

To further reduce the amount of plastic required to fabricate the hub, the rear section of hub cylindrical portion 54 has a recess 76 formed between each pair of elements 17. The full axial dimension of the recess 76 is shown in FIG. 4; and note that the recess does not extend quite to the right edge of stator plates 70. With such an arrangement the thin plastic blade surface adjacent recess 76 is not exposed to the stator coils 72. This is a safety requirement of Underwriter's Laboratories for plastic blade elements in that if the plastic used for the blade is not self-extinguishing, the material must be protected. One method is with fire preventing paint. The paint must be applied where there is likelihood of flame contacting plastic. Therefore, the present design surrounds coils with a circular flange where the paint is applied; otherwise the entire fan blade might require this paint.

Referring now to FIGS. 7 and 8 which illustrate a modified fan construction embodying features of the present invention, there is shown a fan blade generally designated 78 having a cup-shaped hub 80 and five blade elements 82 integrally molded from a resin plastic material. The hub 80 has a circular end portion 84, a cylindrical skirt portion 86 having the blade elements 82 extending from the outer surface thereof, and an annular portion 88 positioned centrally of the end portion and concentrally of the skirt portion. The hub 80 is also provided with a molded-in place metal insert 90 which is partially enclosed by the annular portion 88 and is rigidly secured thereto against either axial or rotational movement in any suitable manner as will be readily apparent to those skilled in the art. The insert 90 is adapted to slidingly fit over shaft 92 of electric motor 94 and has an end positioned outwardly from the hub end portion 84 provided with a set screw 96 to secure the insert, and thereby the fan blade 78, to the motor shaft.

In order to prevent deterioration of the plastic fan blade 78 as a result of overheat conditions during the abnormal operating conditions hereinbefore described, the

hub **80** is provided with a series of circumferentially spaced apertures **98** extending through the end portion **84** positioned radially above and adjacent to the radial outer surface of the annular portion **88**. The apertures **98** communicate with a series of air flow passages **100** formed internally of the hub **80** and defined by the side surfaces of radially extending walls or vanes **102**, the inwardly facing surfaces of the hub end portion **84** and skirt portion **86**, and the radial outer surface of the annular portion **88**. The number of vanes **102** may correspond to the number of apertures **98** so that each aperture communicates with a single air passage **100**. Such an arrangement imparts high structural rigidity to the hub **80**. It is to be understood, however, that a lesser number of vanes **102** would be acceptable when the fan blade **78** is made from a plastic material having the necessary strength and rigidity characteristics; for example, two adjacent apertures **98** may communicate with a single air passage **100**, in which case the number of vanes **102** would be one-half the number of apertures **98**, whereby the amount of plastic material required to form the blade may be correspondingly reduced.

The vanes **102** have a lower portion extending radially upwardly from the hub annular portion **88** and curving in the direction towards the motor **94** to merge with an upper portion extending substantially the full length of the hub skirt portion **86** and tapering outwardly and in the direction of the motor, as best seen in FIG. 8. With this vane construction, the passages **100** function during operation of the fan as a centrifugal blower. In normal operation, air is drawn in through the apertures **98** and directed in a combined axial and radially outwardly path as indicated by the arrows in FIG. 8. The various parts of the plastic hub **80** and adjacent surfaces of the motor **94** are thus subjected to currents of cooling air and the plastic of the fan blade is thereby maintained at an acceptably low temperature. It should be noted that the aforementioned centrifugal blower effect and cooling air flow occurs during normal operation of the fan irrespective of the direction in which the fan blade **78** is being rotated.

When the air flow generated by the fan is severely restricted as in the "closed window" situation, the apertures **98** permit cooling air to flow through the hub **80** in the manner shown in FIGS. 5 and 6, depending upon the direction of rotation of the fan blade. As previously described, restriction of the fan output causes the motor to become overloaded and consequently to overheat. Moreover, this overheat condition is aggravated by the fact that the cooling air flow over the motor is itself reduced. By providing the apertures **98** which result in a cooling air flow through the hub **80** and over the motor **94** because of the large pressure differential existing between the two sides of the fan blade **78** in the restricted flow condition, the plastic hub components are prevented from becoming heated to the temperature at which the material would soften and thereby result in distortion and failure of the fan blade.

Other modifications and variations of the present invention are possible in the light of the above teachings. It is, therefore, to be understood that all such variations and modifications within the spirit and scope of the invention are intended to be included within the appended claims.

What is claimed is:

1. In a fan construction, a fan blade made of plastic which will deform under fan operating forces at temperatures slightly above the normal operating range; said blade having a plurality of elements extending outwardly from a central hub; a reversible motor having a shaft for drivingly receiving said hub; said hub having a series of air passages for directing cooling air flow through the hub to prevent the temperature of the hub from rising to a level to deform the hub during abnormal fan operation wherein the air flow of the fan is substantially obstructed in either direction of rotation.

2. The fan construction of claim **1** in which a metal insert is positioned in the central portion of said hub to engage said shaft, said air passages being formed in said insert.

3. The fan construction of claim **1** wherein said hub is formed with a series of inwardly extending, axially oriented vanes for circulating air adjacent said motor to provide motor cooling.

4. The invention of claim **1** in which said blade elements have a helical shape so that centrifugal forces produced by rotation of the blade do not tend to change the shape of the blade elements.

5. In a fan construction, a plastic fan blade having a plurality of blade elements extending radially outwardly from a central hub; an annular series of alternately spaced openings and solid sections within one end of said hub facing generally an axial direction; a metal insert centrally positioned within and secured to said hub end; said insert having an annular series of alternately spaced openings and solid sections radially inwardly positioned from said series within said hub for directing cooling air through insert; said insert series and said hub series being circumferentially arranged with respect to each other so that a solid section within the insert series is radially aligned with an opening in the hub series and an opening in the insert is aligned with a solid section in said hub series.

6. In a fan construction, a plastic fan blade having a generally cup-shaped hub and a plurality of blade elements extending radially outwardly from the side walls of the hub; an electric motor adapted to fit partially within said hub and having an output shaft; a metal insert centrally positioned within and secured to one end of said hub; said insert having a central opening adapted to be secured to said motor shaft; said insert having an annular series of spaced air passages for permitting air flow through the insert to disperse heat from said motor and thus prevent the temperature of said plastic hub from reaching a level where it would deform, said hub having an annular series of spaced air passages surrounding said insert.

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