Aug. 15, 1967 S. F. McCLATCHIE 3,335,482

ASSEMBLY OF BLOWER WHEELS

Filed Oct. 18, 1962 3 Sheets-Sheet 1

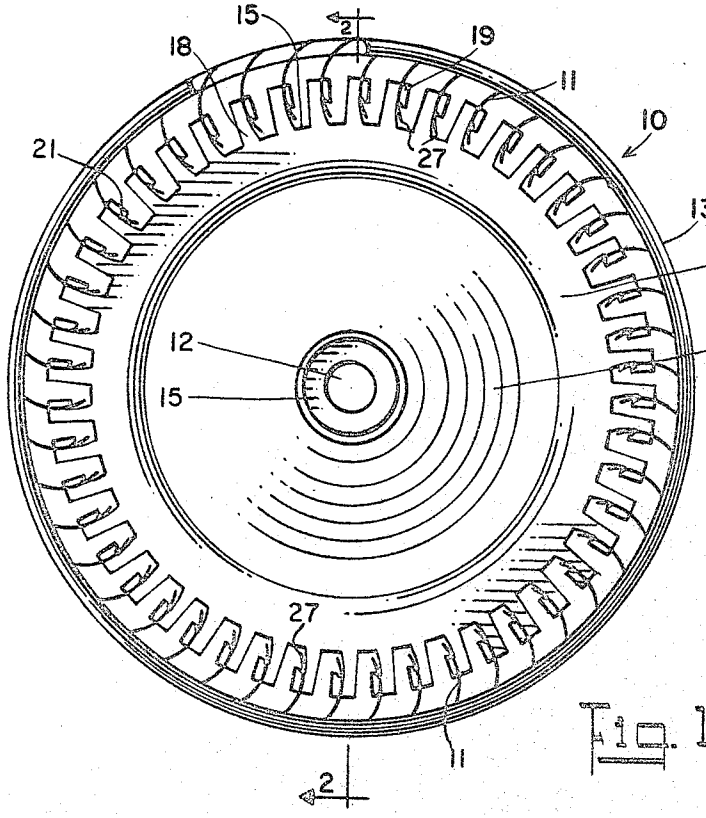


Fig. 1

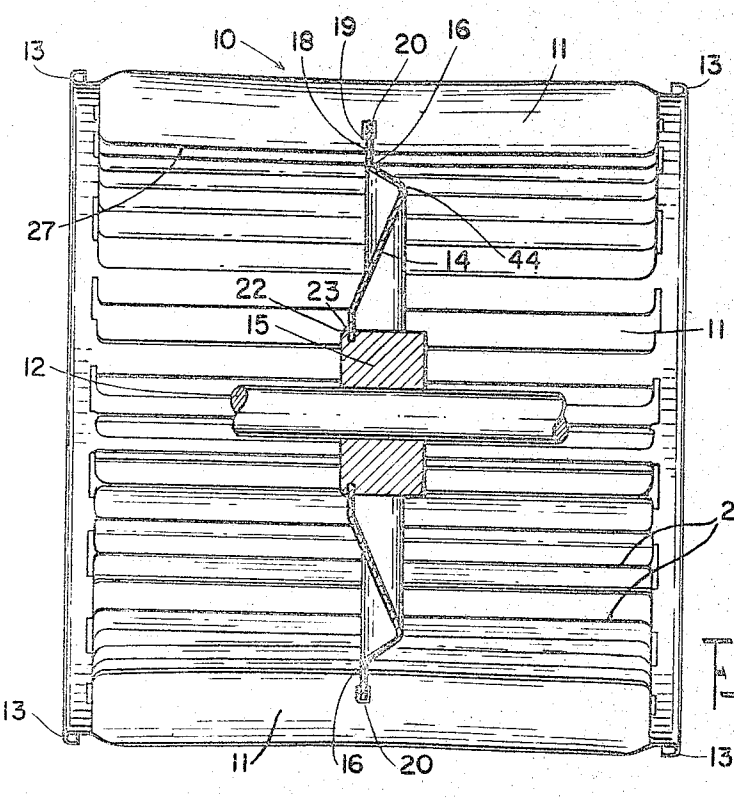


Fig. 2

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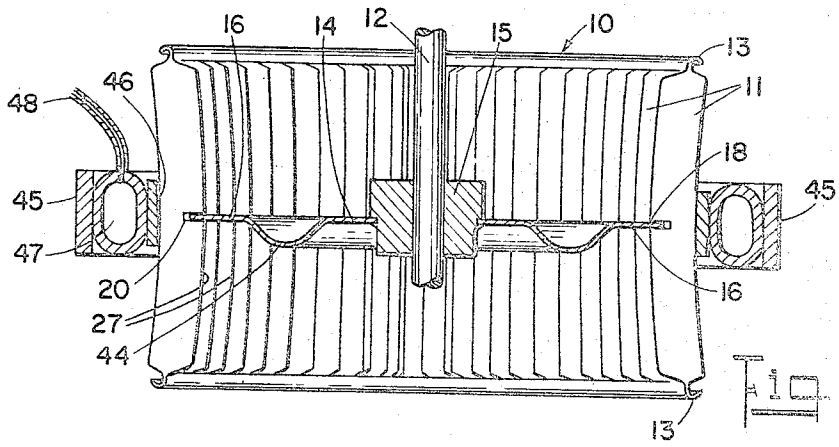


Fig. 8

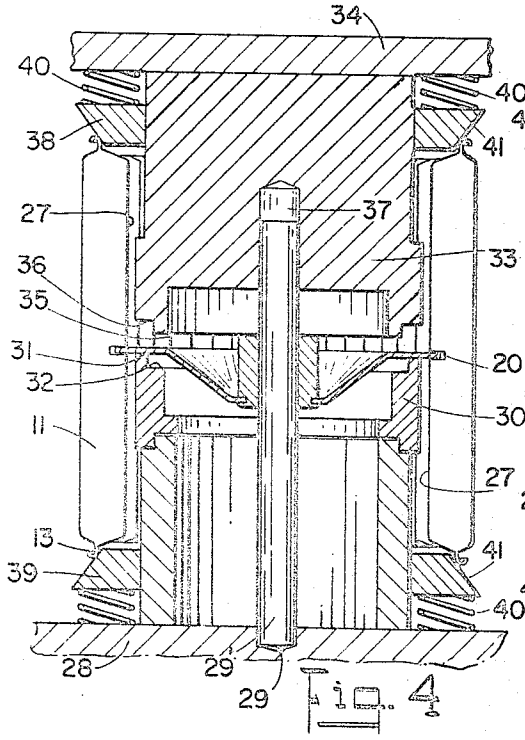


Fig. 4

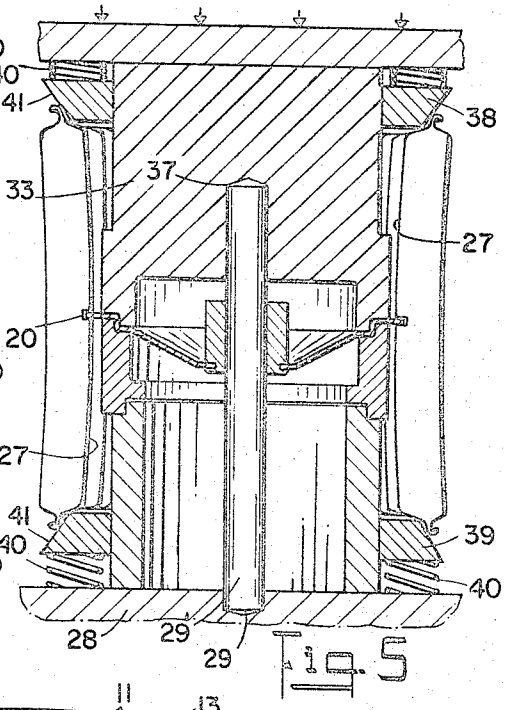
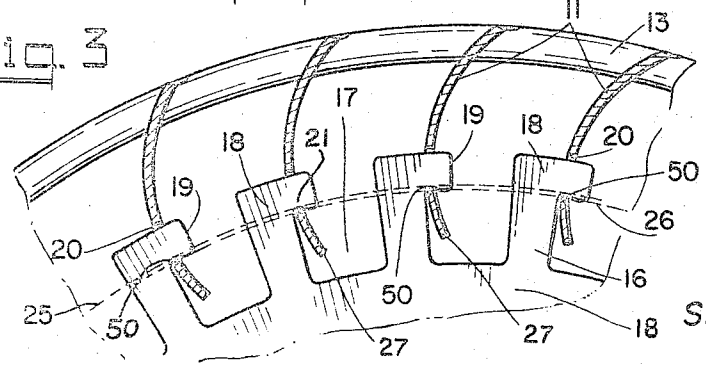


Fig. 5

Fig. 3



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ASSEMBLY OF BLOWER WHEELS

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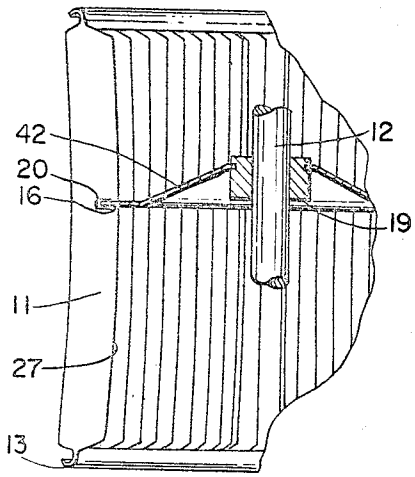


Fig. 6

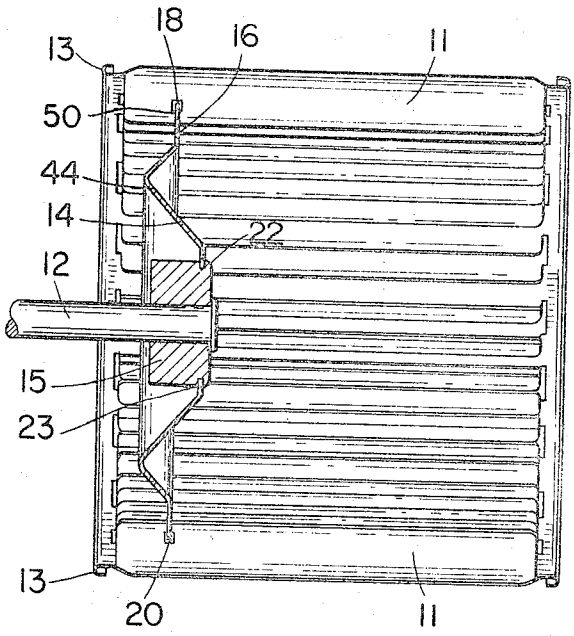


Fig. 7

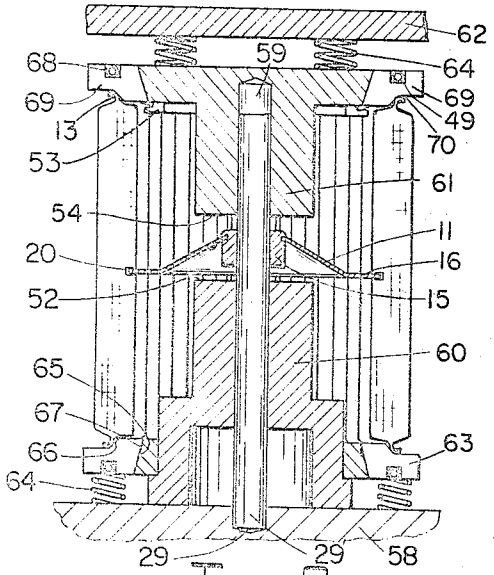


Fig. 9

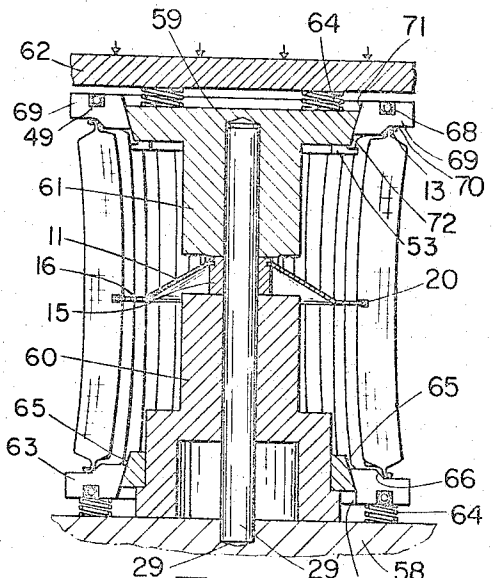


Fig. 10.

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3,335,482

ASSEMBLY OF BLOWER WHEELS

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Filed Oct. 18, 1962, Ser. No. 231,484
3 Claims. (Cl. 29—156.8)

This invention relates to fluid propelling apparatus and more specifically concerns improvements in means for connecting a cylindrical array of blades to a center support disc in a centrifugal blower wheel intended to be operated under severe high speed and acceleration conditions, and improvements in methods for assembling such wheels.

Radial flow blowers as used in domestic heating and air conditioning service comprise blower wheels of the centrifugal type having a plurality of blades arrayed in parallel around the periphery of the wheel, forming a cylindrical shell, and the blades are held in circumferentially spaced relation by end rings secured to the blade ends. Such end rings have large apertures serving as fluid inlets to the interior of the wheel. The blade cage commonly includes an internal support member such as a spider or disc-like member which has its peripheral portion secured to the blades intermediate their ends, and which also has a central aperture fixed on a coaxial hub which provides a means for mounting the wheel concentrically on the drive shaft.

Various means are employed to attach the blading in fixed concentric relation to the shaft. Such attachments must have adequate strength to transmit force to the blades when propelling air, and also to withstand the loads due to acceleration and high speed running. In one assembly method favored in building low-speed wheels because of its low cost, the outer periphery of the disc is connected with a cage of curved blading by forcing the disc in an axial direction into the end of the wheel as a press fit to engage the somewhat resilient inner margins of the blades frictionally. The ends of the blades are held in end ring structures of any suitable form which take up the loads transferred to them by the outward bowing of the blades. Some deformation and metal forming occurs at the junctions of the blade and disc margins, aiding the frictional locking produced by outward deflection of the blades.

In an operating blower the tensile stress in the end rings is increased in direct proportion to the centrifugal force applied thereto due to the mass of the end rings and other stresses are increased due to loading of the blades by the air stream. While locking means as described may serve adequately at low wheel speeds and under gentle accelerations, such assembly method is unsuited to higher speed wheels or to wheels subject to high acceleration loads.

At higher rotational speeds conventional blower wheels vibrate, becoming unstable and quickly break up. Unless concentricity and balance can be assured at the highest speeds, failure is likely. The causes of failure appear to be various, the principal cause perhaps being the disengagement of the blades from the center disc or discs, and other causes being the bowing of blades under centrifugal force producing change of blade pitch and oscillation. These deformations, as well as others, result in pronounced variations of load in the end rings and blades, both of which have been observed to fail at moderately high speeds.

The prior art has sought to provide blade attachment means for securing the wheel concentrically with a drive shaft by means of a center disc in a positive manner, as by riveting or welding each blade to the disc periphery, and by aperturing the blades and swaging hook projections extending therein from the disc margin. While blower wheels so assembled can be run at higher speed, such constructional methods are considerably more costly of manufacture.

I have found that when the array of blades of a centrifugal blower wheel is resiliently deformed out of its cylindrical shape so that the inner margins of the blades are displaced radially inwards with respect to their ends which are fixed in annular end rings, and a shaft-supported center disc inside the blower wheel is connected concentrically with the blade array by any positive attachment means so as to maintain the prestressing of the blades and end rings, the resulting blower wheel may be spun safely at appreciably higher running speeds.

I therefore provide, according to the invention, an improved wheel construction characterized by positive connection of blower wheel blades with a center disc, wherein the blades are connected with the periphery of a center disc in a pre-stressed condition, being inwardly deflected along their spans with respect to their ends, and the end ring structures are stressed under tangential compressive load when the wheel is at rest, resulting in a wheel having an increased safety margin at higher rotational speeds.

The wheel assembly produced by the practice of the invention is particularly advantageous when the end rings each consist of a rolled bead formed along an edge of a metal strip having pressed-out integral blades connecting the edges, since such structure has a highly unfavorable aperture ratio for high speed running, i.e., the ratio of the inner diameter to the outer diameter of the ring is nearly unity.

In carrying the invention into effect, I provide in a blower wheel assembly, a misfit relation between interlocking elements carried by the blades and by the center disc margin, such as co-operating apertures pierced in the blades and peripherally spaced hooks formed on the margin of the center disc, so that the blades become bowed inwardly with respect to their ends by reason of their attachment to the hooks, thereby placing the hooks and disc under radially outwardly directed tension and the end rings under compressive stress radially and tangentially. It is immaterial whether the assembly is made by first connecting a cylindrical array of apertured blades with a center disc and thereafter the ends of each blade are forced radially outwardly in assembling into final relation with respect to end rings, or whether the blade cage is first assembled to hold the blades fixed by their ends in end rings and the subsequent operation of joining the disc with the blades by shrinking the disc margin causes the mid-length portions of the blades to be drawn inward into final assembled relation.

In a preferred manufacture, the assembled blade cage including integral end ring structure is first connected with the margin of a center disc in any positive manner of uniting edges of transverse elements to withstand centrifugal load, and the center disc is then die formed to effect a dishing or drawing of the material near the outer edge, causing a shrinking of the outer diameter and consequentially pulling the blades inwards against the end ring structure.

It also lies within the scope of the present invention to apply radially inwardly directed force to each blade of a cylindrical shell array of blades to constrict the shell diameter intermediate the ends by an amount sufficient to effect the pre-stressing of blades and end rings, then connecting the center disc margin with the blades in any positive manner to maintain the constricted diameter condition.

Moreover, the interlocking means may equally satisfactorily consist in the provision of hooks extending from the blades for engaging apertures in the center disc margin, and many other interlocking means for providing positive connection between the parts are also contemplated for use in practicing the invention.

It is therefore a primary object of this invention to provide a double inlet blower wheel wherein a supporting center disc within the interior of the wheel has its peripheral portion directly connected with the blades by a simple and economical positive holding connection which acts to secure the blades intermediate their ends in fixed radial relation with respect to the axis of the wheel and to apply a permanent radially inwardly directed force on each blade.

It is also an object of the invention to provide an improved center support disc and means to assemble the disc securely to a cylindrical array of blading in a radial flow blower wheel to pre-stress the blades and induce tangential compressive stress in the end rings for offsetting deformation due to high speed running.

It is another object of the present invention to so mount a center disc in a blower wheel that each blade is positively held connected therewith in predetermined radial relation with the wheel axis and so that the disc is under radially outwardly directed tensile stress induced by inward deflection of the blades loaded as end-supported beams having a force applied intermediate their ends.

Still another object of the invention is to provide a mounting and assembly method for connecting a center disc into a blower wheel to ensure concentricity in the assembled product under high speed and acceleration forces by maintaining a predetermined stress condition in the end ring structures in opposition to the stress produced in such structures by centrifugal forces.

One further and important object of the invention is to produce a blower wheel having only a single center disc and characterized by quiet running and excellent stability even at high rotational speed.

Yet another object of the invention is to provide a blower wheel structure of superior rigidity and stability over a wide range of speed yet simple to manufacture and low in cost.

The invention may be the better understood as to its principles and practice from a study of the following disclosure of its preferred embodiments, to which the appended drawings relate, and wherein:

FIGURE 1 is an end view of a double inlet blower wheel according to the invention having stressed blades connected by hooks with a single support disc;

FIGURE 2 shows a diametral axial cross-section taken on line 2—2 of FIGURE 1, showing a blower wheel as assembled with resiliently bowed blades and compressively stressed rings;

FIGURE 3 shows in greatly enlarged detail, a cross-section through the disc hooks and blade slots of the wheel in FIGURE 1;

FIGURE 4 shows a preferred die press organization prior to shrink-forming assembly of a center disc into a blower wheel;

FIGURE 5 shows the apparatus of FIGURE 4 at the conclusion of the shrink-forming stroke, the blower wheel being in axial diametral section;

FIGURE 6 is a partial section view similar to FIGURE 2 wherein the blower wheel assembly illustrates shrink-forming of a center disc margin by a dishing operation;

FIGURE 7 is a diametral axial cross-section of another form of blower wheel according to the invention modified for single inlet operation;

FIGURE 8 shows an apparatus for an alternative assembly method wherein the diameter of a blade cage is reduced initially, followed by insertion of a smaller center disc; and,

FIGURES 9 and 10 show yet another alternative assembly apparatus before and after blade pre-stressing by permanent enlargement of the end ring diameters with respect to a center disc.

Referring to FIGURE 1, a preferred blower wheel assembly comprises a blade cage **10** whose blades **11** are aligned parallel to the axis of shaft **12** and arrayed in uniformly spaced relation concentrically therewith as a cylindrical shell form open at its ends. Annular end flanges **13** comprising rolled steel rim portions integral with and forming terminal extensions of the blades, are circular in end projection and lie in parallel planes normal to the wheel axis, the rings having an inner diameter greater than the inner diameter of the shell. Such blade cage structure and the integral rim flanges—hereinafter referred to as end rings—are well known in the art, being disclosed in Patent 459,563 (Canada) to Robert Mayne, and per se form no part of the present invention. The blower wheel is assembled with a center disc **14**, a hub **15**, and a drive shaft **12**, all being of known form and fully described in prior publications, the modification of the connection between the center disc and the blading to slightly deflect the blades inwardly comprising the essential features of the present invention, as will be described more particularly hereinafter.

Referring also to FIGURES 2 and 3, the center disc **14** has a peripheral interlocking portion **16**, disposed in a plane at right angles to the shaft axis, having radially-inwardly extending recesses **17** spaced uniformly apart. Hook shanks **18** extending between the recesses **17** terminate in laterally broadened hook portions **19** all extending in the same direction, i.e., preferably facing the convex side of the curved blades. The portions **19** have a radial span sufficiently less than the radial span of the blade apertures **20** to allow their entry therethrough on assembly. A throat portion **21** of the lateral projections, formed adjacent each shank **18**, lies radially outwardly of the remainder of the projection, being wide enough to seat upon the inner edge **50** of a blade aperture **20**.

The center disc is permanently secured in any suitable manner to the hub **15**, as for example by swaging of the end **22** over the inner margin **23** of the disc against hub shoulder **24** while the parts are held in a jig to ensure concentricity.

The outer periphery **16** of the disc may be recessed by means of a multiple or indexing type of metal punch such as are employed in making motor stator or armature laminations. The punching operation is carried out so as to ensure that the hook throats **21** will lie along the circumference of a circle **25** having its center in the wheel axis or hub axis, whose diameter exceeds by a slight amount the diameter of a contacting circle **26** tangent to the inward hook projection margins **19**. It is essential that the diameter of circle **26** be not less than the diameter of a circle (not shown) which may be drawn to enclose the inner edges **50** of the blade apertures **20**, to permit assembly by the steps hereinafter to be more fully described.

The blading **11** and the apertures **20** are punched from flat strip steel stock on compound or on progressive dies, the blade forming and cage rolling operations comprising no part, per se, of the present invention, and being produced, for example, by the method outlined in the patent referred to. The method disclosed consists generally in forming a pair of strips with integrally formed blades transverse to its length, which are laminated in staggered relation and then rolled into cylindrical shell form as a self-supporting unitary structure. The blading may also be straight or formed to a profile other than as taught by the patent which exemplifies one practical form of blower

wheel, and it is not intended to limit the practice of the invention in any way to such disclosure.

The assembly of the cage **10** with the disc **14** is simply effected by centering the disc on the cage axis so that the recesses **17** are aligned with the inward blade margins **27**, and the disc is then moved axially inwardly of one end to lie in the plane of the blade apertures **20**. When the hook ends **19** are registered on the blade apertures, a turn of the disc about its axis through an angle of a few degrees will pass the hook ends into apertures **20** freely or under a light force to spring the blades inwardly if the inner margins of lateral portions **19** have a slightly smaller diameter than the diametral distance across the wheel between aperture edges **50**. When the disc and the cage are in this temporarily assembled relation, as shown in FIGURE 4, the blower wheel is incapable of withstanding rotation due to the loose fit between disc and blades.

Referring additionally to FIGURES 4 and 5, a preferred apparatus is shown for simultaneously assembling the disc in rigid, locked relation with the blades and for achieving the desired concentricity of the blading array with the wheel axis as well as imparting tangential compressive pre-stressing to the end rings.

The apparatus comprises a die bed **28** apertured at **29** to receive an end of a hub-guiding dowel **29'** firmly embedded vertically therein and of the same diameter as shaft **12**, having a lower forming die **30** supported from the bed in contact with the disc **14**. The die comprises an outer flat surface annular area **31** radially spaced from the blade inner margins **27**, and an axial stepped inner annular area **32**, both lying wholly within the planar portion **16** of the center disc. An upper die **33** secured to ram structure **34** has a forming face complementary to that of die **30**, comprising a raised outer annular area **36** and a depending inner annular ring **35**, respectively superposed above the areas **31** and **32** of the lower die. A bore **37** in the upper die body is a close clearance fit for guidedly receiving the upper end of dowel **29'**. The arrangement described assures that the dowel is firmly held immovable at both ends during the closing movement of die faces **36** and **35** with respect to die faces **31** and **32**, whereby the outer diameter of the disc is shrunk. This provision assures that the bore of hub **15** will be assembled in true concentric relation with end rings **13**, the latter being held during the forming of the disc by positioning rings **38** and **39**, and also assures that the disc will be formed with its margin in a plane transverse to the wheel axis.

The upper and lower die support bodies are cylindrical on their outer surfaces and serve to guide annular ring dies **38**, **39**, which are respectively slidable on the support bodies. Springs **40**, **40'** respectively urge the positioning dies toward the disc and into contact with rims **13** by the outwardly sloping opposed die faces **41**. The latter have a radial extent and outer diameter chosen to ensure that the wheel end rings will be held concentric with the hub bore throughout the shrinking operation, as described below.

As the die ram **34** moves downwardly in the forming stroke, the sloping faces **41** engage the end rings, bringing them into roundness and into concentricity with dowel **29'**. As the dies close up, the peripheral portion **16** of the disc is formed with a lateral flange or axial groove **49** between the hook roots and the dished disc **14**, thereby contracting the periphery. The result, as depicted in exaggerated form in FIGURE 5, is that the blades are bowed inward with respect to the end rings. The degree of bowing in an actual assembly will be relatively inapparent in a cursory glance, and will be less than shown in FIGURE 2. Close inspection of wheels assembled according to the invention will reveal that there is in fact a slight but perceptible bow of the outer margin of each blade, both radially and circumferentially. In wheels where a forming draw produced about 0.080 inch shrink, in a nine inch disc, the blades were bowed about 60 thousandths.

The degree of drawing required to effect the prestressing desired will obviously vary with the gauge and the diameter of the center disc, and with the initial clearance between the hook ends **19** and throats **21**, as well as with the diameter of a circle along which aperture edges **50** lie. Those skilled in the art of forming sheet metal will readily understand that the diametral shrinkage of a disc results from metal drawing involving lateral displacement of disc material close to the outer margin, as when an annular groove or axial offset is pressed. Also, the radial location of an annular groove or offset should lie within a range of from about 10 to about 30 times the thickness of the disc from the margins of recesses **17**. Excessive pad pressure on the area of the disc portion **16** lying outwards of the groove or offset being drawn, such as would inhibit diametral shrinkage, should be avoided.

In a number of successful embodiments the discs for a 12 inch blower wheel designed to be used in domestic heating service at a tip speed of 400 feet per minute, were fabricated by the center disc shrinking operation described, which produced an axial offseting of the disc periphery at a distance 5/8 inch inward from the margins of recesses **17**, the die stroke being adjusted for diameter reductions ranging from about 0.060 to about 0.185 inch. The wheels were then tested under load at high rotational speeds and severe acceleration. All wheels sustained a running speed of 8,000 feet per minute and withstood repeated rapid starting and stopping four times a minute for 100 hours. On inspection no flaw or incipient failure was revealed.

In an alternative assembly method the discs may be planar at the time of assembly into a blower wheel by shrinkage, and the dies **30** and **33** have their faces shaped to produce a simple dish form as shown at **42** in FIGURE 6.

A continuous disc, that is to say, one having no central hub aperture, may be employed with either assembly method, and the operation of aperturing for hub mounting carried out by use of a compound die (not shown) which shears out the hub aperture at the end of the shrink-forming operation on the disc. The blade cage with integral center disc so formed is then staked or swaged on a hub as by peening or pressing the margin **22** against disc margin **23**.

In a further alternative assembly method, a blade cage for a blower wheel may be assembled with integral end rings and parallel blades according to conventional practice, and inward deflecting force applied uniformly exteriorly of the cage to contract the diameter of the cylindrical shell, as in FIGURE 8. In this embodiment a disc **14** has its peripheral portion **16** slotted as in FIGURE 3 to produce radial recesses **17** separating hooks **18**, and may be planar, but preferably is formed as shown with an annular groove **44** to provide the desired stiffness. The diameter of a circle **25** tangent to the hook throats **21** is in this case made smaller than the diameter of the locus of inner edges **50** of apertures **20**, so that unless the blades are deflected, the hooks cannot be passed through the blade apertures. In order to effect assembly, the ring **45** of fixed inner diameter larger than the cage is placed around it in a plane transverse to the cage axis and at the desired position intermediate the ends of the wheel. A pressure-distributing band **46** of rubber or a rubbery material is wrapped closely around the cage inside of ring **45**. An expandible hollow tube **47**, for example a rubber tube, is inflated pneumatically or hydraulically, as by connecting inflation line **48** to a supply source under suitable pressure (not shown) until the desired deflection of the blades has been produced.

When the blades are in their deflected condition, the center disc may be axially inserted in one end of the blower wheel and given the fractional turn rotation about its axis necessary to pass the hook ends **19** through the blade apertures **20**. While the disc is held with the aperture edges **50** radially aligned with corresponding hook throats **21**, the pressure in tube **47** is released. This allows

the blades to spring back as the tube deflates or empties until held by the hooks. The ring **45**, the tube **47**, and the pressure pad **46** are simply removed and the blower wheel is ready for use. Concentricity of the blades and the shaft axis is attained, since the hook throats lie along a precise circle.

According to another variant of the assembly method employing the same inventive principle, the desired blade deflection and compressive pre-stressing of the end rings is realized by expansion, i.e., stretching of the end rings relatively to a center disc after assembly of a conventional blower wheel. Referring now to FIGURES 9 and 10 of the drawing, one form of apparatus for precisely expanding integral end rings in concentric relation with the wheel axis comprises a press bed **58** having a hub-guiding shaft **29'** and a lower and an upper shaft guide block **60** and **61** respectively held in the bed **58** and in the ram **62**. A lower ring-stretching annular die **63** comprising a large plurality of closely spaced sectors having radial walls, has a coil spring retainer ring **68** seated in annular groove **49** recessed into the horizontal lower faces of the sectors, the spring ring being under tension, tending to contract the die. Lower guide block **60** has a radially extending skirt portion **51** spaced above the bed, having a conic outer face **65** of relatively small apical angle complementary to the angle of conic inner faces **67** of each sectoral segment **63**. Die springs **64** disposed between the bed and the under side of the sectors tend to raise them and thus to contract the die diameter as the sectors slide upward on the skirt face **65**.

A blower wheel blade cage **10** is placed with its axis vertical and with its hub **15** engaged by dowel rod **29'**. The lower end ring **13** is seated upon the upper faces of the sectors **63**. A groove **66** is formed to a depth and with such bottom curvature as to enable the end ring to be received therein in seating relation for the purpose of stretching. The upper planar face **52** of guide block **60**, which is normal to the wheel axis, is spaced a short distance below the hub, such spacing comprising, for example, about one inch when the apical angle of the conic faces lies in the range from about 12 to 20 degrees.

Upper guide block **61** has a flange or skirt **53** extending radially at its upper end, formed with an outer conic face **71** of apical angle identical to that of face **65** on block **60**. The block is assembled on the upper end of the blade cage with the upper end of dowel rod **29'** received in its coaxial bore **59**. A sectoral ring-stretching upper die **69** is captive on the block, about skirt **53**, being prevented from dropping by stop means **55** fixed to the block and spaced below the skirt. Spring ring **68** seated in groove **49** recessed in the upper faces of the sectors of die **69** is under tension, tending to contract the die, which has an annular groove **70** recessed in the under side of each sector and which is registered in holding relation with upper end ring **13** of the blower wheel. The lower end of guide block **61** has its planar face **54** spaced above the wheel hub **15**, by a distance substantially equal to the spacing of face **52** below the hub.

As shown in FIGURE 9, the ram **62** has descended carrying block **61** suspended therefrom by springs **64**, to engage respective ends of the blower wheel in die grooves **66** and **70**. As the ram applies further pressure on moving downward to compress springs **64'**, the blades prevent further relative movement of sectors **69** with respect to sectors **63**. As the wheel hub approaches the face **52**, the sectors move down below the conic face **65** against springs **64**, expanding the die. This spreading of the sectors causes the end ring to be stretched beyond the yield point of the metal, thereby enlarging the ring diameter while maintaining it concentric with the axis of rod **29'**. When the faces **54** and **52** have bottomed against the hub, the end rings are permanently enlarged and the blades are deflected inwardly with respect to the end rings. The ram **62** is then raised to lift upper guide block **61** and hence die **69** clear of the dowel rod, and the wheel is lifted out.

While the foregoing description has dealt with an assembly method for stretching the end ring material in the cold state, it is also contemplated that the material may be preheated before loading the wheel in the press so that the end rings are more ductile.

Those skilled in the art will understand that the stretching of the end rings relatively to a center support disc assembled into a blower wheel may be accomplished by other known forms of stretching tools, hence the particular apparatus described is to be understood to be illustrative rather than limiting of the invention. In general, any working of the material that will effect an elongation of the end ring circumference, without significant adverse effects on the blading or the wheel, may be resorted to, including swaging and spinning operations. In carrying such methods into effect, the wheel disc and hub should be held rigidly with respect, to a reference axis and the concentricity of the end rings about such reference axis attained.

While the foregoing description has been directed to embodiments wherein the support disc is located midway of the length of the blower wheel, as in double inlet wheels, the method is applicable equally to single-inlet wheels as shown in FIGURE 7. In this embodiment, the disc is not centered along the axis, but is instead located nearer one end ring. In general, apertures **20** will be located not closer to a blade end than about fifteen times the blade thickness, and preferably will lie about one-half inch or more from the blade end.

I claim:

1. The method of assembling a single center support disc within a blower wheel having peripherally spaced blades arrayed as a shell with the outer margins of the blades lying in a cylindrical surface and the ends of the blades integrally joined with end rings, said method comprising the steps of piercing slot openings in said blades at a radius intermediate the inner margins of the blades and the inner margins of the end rings, forming a plurality of hook fasteners spaced about the periphery of the disc, said fasteners comprising radial shank portions terminated by lateral hooks having inward margins lying along tangents of a common circle centered in the disc axis, said hooks having throat notches formed adjoining said shank portions, said hook notches and said inward slot margins having radial positions such that at least some of said slot margins are disposed in interfering radial relation, inserting said disc axially into said wheel, rotating said disc to enter said hooks into said slots and to overcome interference by springing said blades inwardly to seat said slots in said hook notches to form a self-sustaining wheel assembly, holding said assembly between dies, and axially offsetting an annular portion of said disc adjacent said shank portions to draw the margin of said disc radially inwardly a distance sufficient to effect inward bowing of all said blades and to generate compressive tangential stress in each end ring.

2. The method of claim **1** wherein said annular portion is formed by stepped complementary dies to form a cylindrical band inwardly adjacent to said shank portions and said compressive tangential stress is at least as great as the maximum tensile stress that would be developed at operating speed due to centrifugal forces on said blades.

3. The method of assembling a single center support disc within a blower wheel comprising a pair of concentric bands assembled in cylindric contacting relation, each band carrying a plurality of blades integrally joined by their ends with marginal portions, the marginal portions being rolled into end rings and the blades of one band initially lying at radial positions outwardly of the radial positions of the blades of the other band, said method comprising the steps of piercing slot openings in said blades intermediate said end rings adjacent the inner margins of said blades, forming said wheel whereby alternate

slot openings differ in radial location, forming a plurality of hook fasteners spaced about the periphery of the disc having shank portions projecting radially and terminating in lateral hooks having inward margins lying along tangents of a common circle centered in the disc axis, said hooks having throat notches formed adjoining said shank portions and said inward margins being a free fit when assembled into blade slots of blades of one band but being an interference fit with respect to blade slots of the blades carried by the other band, inserting said disc axially into said wheel, rotating said disc to enter respective hooks into blade slots and to overcome interference encountered by springing said blades inwardly to seat said slots in said notches to form a self-sustaining wheel assembly, holding said assembly between dies, and axially offsetting an annular portion of said disc adjacent said shank portions to draw the margin of said disc radially inwardly a distance sufficient to effect inward bowing of all said blades while holding said end rings concentric with the disc axis, said bowing being sufficient to generate permanent compressive tangential stress in each end ring and to align the outer margins of all said blades to lie in a common surface of rotation.

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