Feb. 16, 1960 E. A. STALKER 2,925,216

AXIAL FLOW COMPRESSOR ROTOR CONSTRUCTION

Filed Sept. 10, 1952 2 Sheets-Sheet 1

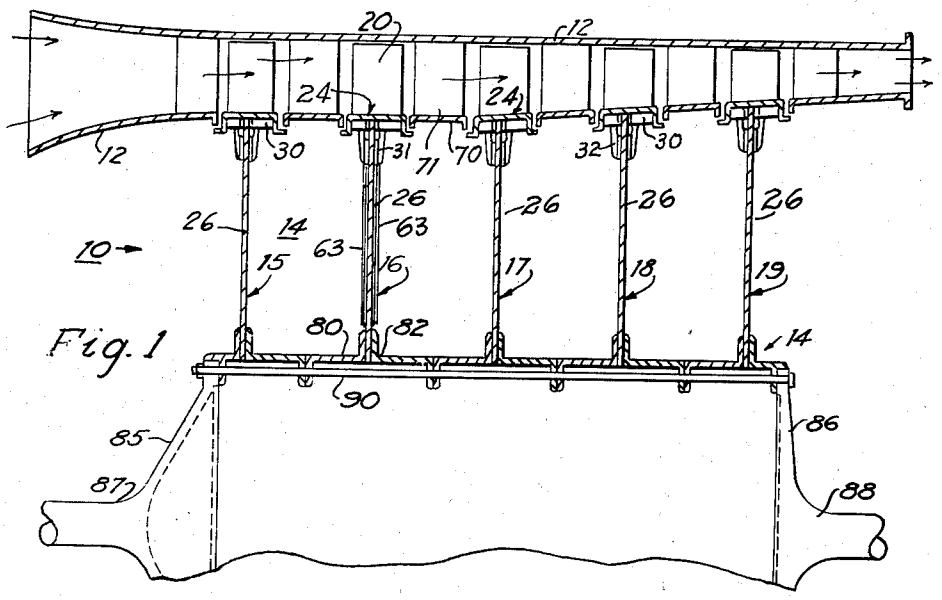


Fig. 1

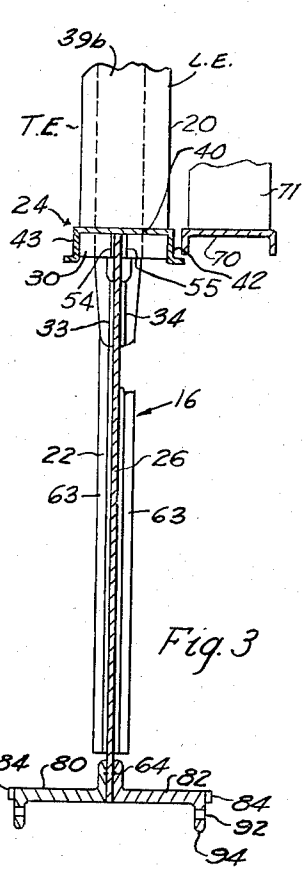


Fig. 3

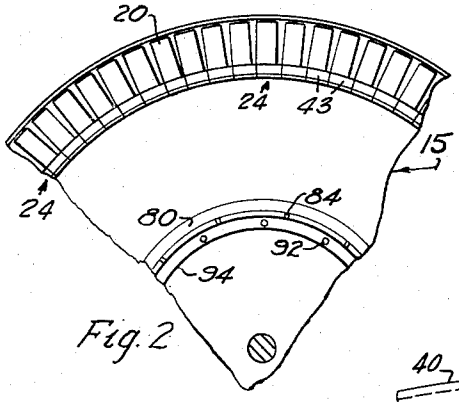


Fig. 2

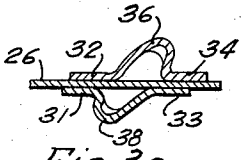


Fig. 3a

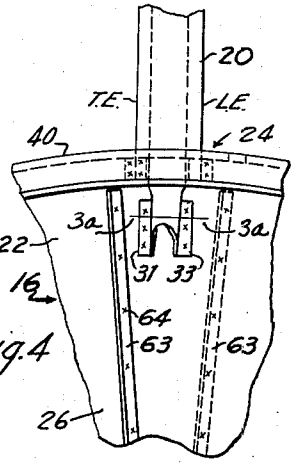


Fig. 4

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AXIAL FLOW COMPRESSOR ROTOR CONSTRUCTION

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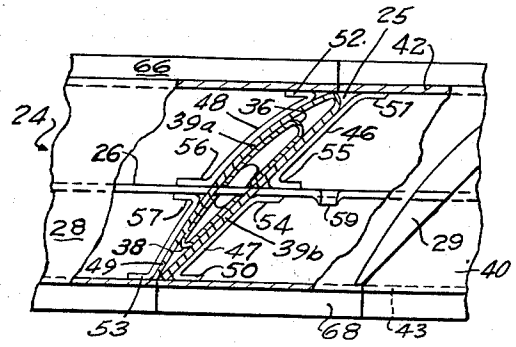


Fig. 5

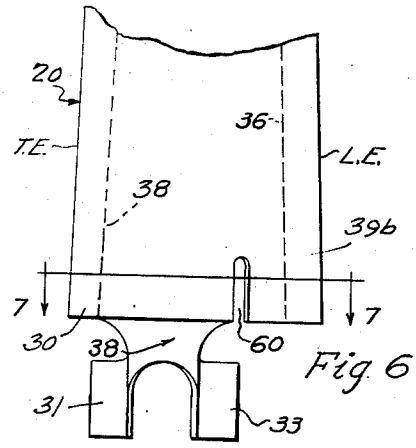


Fig. 6

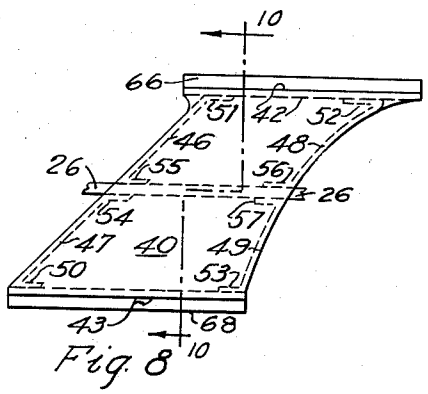


Fig. 8

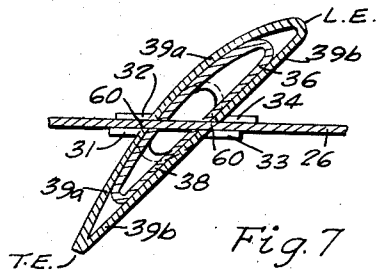


Fig. 7

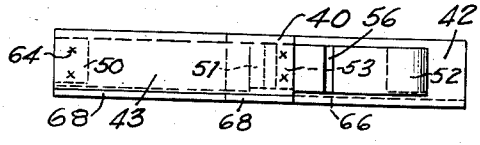


Fig. 9

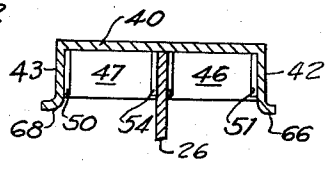


Fig. 10

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2,925,216

AXIAL FLOW COMPRESSOR ROTOR CONSTRUCTION

Edward A. Stalker, Bay City, Mich., assignor to The Stalker Corporation, a corporation of Michigan

Application September 10, 1952, Serial No. 308,862

13 Claims. (Cl. 230—122)

This invention relates to compressor rotors for axial flow compressors and particularly to the structure of the bladed wheels of which the rotor is comprised.

Reference is made to my other applications, namely, "Axial Flow Compressor Construction," Ser. No. 42,565, filed August 5, 1948, now Patent No. 2,649,243, and "Rotor Construction," Ser. No. 167,981, filed June 14, 1950, now Patent No. 2,772,851.

An object of this invention is to provide a bladed wheel construction of soldered sheet metal construction.

Another object is to provide a soldered sheet metal bladed wheel wherein the soldered joints are readily inspected visually.

Still another object is to provide a wheel adapted to be stacked between end disks.

The above objects are accomplished by the means illustrated in the accompanying drawings in which:

Fig. 1 is a fragmentary axial section through a multistage axial flow compressor according to the invention;

Fig. 2 is a fragmentary front view of a wheel;

Fig. 3 is an enlarged fragmentary section of the wheel;

Fig. 3*a* is a fragmentary section on line 3*a*—3*a* in Fig. 4;

Fig. 4 is an axial view of a fragment of a wheel;

Fig. 5 is a radial view of a fragment of a wheel rim with the rim partly cut away;

Fig. 6 is an axial view of the inner end portion of a blade and stem assembly;

Fig. 7 is a section on line 7—7 in Fig. 6 showing the blade assembled on the wheel disk;

Fig. 8 is a radial view of a rim segment;

Fig. 9 is a rear axial view of the segments of Fig. 8; and

Fig. 10 is a section on line 10—10 in Fig. 8.

A compressor changes the density of the fluid flowing through it and in an axial flow machine this change is accomplished by adding velocity to the fluid and then slowing it down by diffusion. That is the fluid is given sufficient whirl speed, so that when it is slowed down there is a significant change in density. Tip speeds of the blades are considered a criterion of whether a machine is a compressor or a simple fan. Compressors are considered to operate in the range above 400 feet per second, since not until this speed is reached with air is there a change in density significant for engineering purposes. At this speed the average density change is about 3% which is just above the accuracy of common experimental measurements in industry.

When tip speeds exceed 400 f.p.s. the structural problems become very difficult and increase in severity as the tip speed approaches the velocity of sound or even exceeds it for some compressors.

At these high speeds new problems arise. It becomes difficult to provide blade attachments which are economical and strong. It also becomes difficult to provide rim segments which can sustain the high centrifugal loads without deformation and failure.

Successful high speed compressor rotors have employed solid blades which had heavy blade bases. These bases are fitted into a heavy hub rim which is suitably grooved to receive them. The heavy blades require heavy blade bases and these in turn require heavy hub rims. In addition the slotting of the rims to receive the blade bases destroys the peripheral continuity of the rim (to resist peripheral stresses) leaving segments between blades which not only do not aid the hub in carrying its load but actually adds to the centrifugal load on the hub, since as just remarked, the slots preclude the use of these segments in carrying the peripheral stresses.

In the present invention the blades are made hollow of light sheet metal construction. Blade bases are not required and the centrifugal loads of the blades are carried directly to the central plate or disk as the main structure for resisting the centrifugal loads. The rim is essentially a closure and at its ends is supported on the blades.

The blades have streamline blade sections tapering with increasing thickness inward from the leading and trailing edges. Such sections are particularly important for compressors to achieve satisfactory pressures with satisfactory efficiency.

Thus by making the blades of limited weight, the centrifugal load of the blades is greatly reduced. Since this load is small and limited and because the blade bases are eliminated and because there is no heavy rim needed to accommodate blade bases, the hub disk can be of limited thickness and weight adapted to sheet metal construction.

The various parts of each wheel are soldered together. Since the failure of any one part such as a blade, may cause the part to pass through the machine and destroy the other blades, it is imperative that all joints be good ones. A method of visually inspecting all joints is therefore highly desirable, before final assembly of the individual wheel units, to assure that each machine is structurally sound.

In axial flow wheels the blades have their leading edges (L.E.) and trailing edges (T.E.) extending radially. The inlets and exits of the fluid flow passages between the blades are at about similar distances from the axis of rotation. The axial lengths of these passages are of the same order of magnitude of the maximum blade length or substantially less. The flow passages discharge their pumped fluid rearward along the axis of rotation.

Referring now to the drawings and particularly to Fig. 1, the compressor is indicated generally as **10** and is comprised of the case **12** and the rotor **14**. The latter is composed of the individual wheels **15—19**. A typical wheel **16** or **15**, as shown in the Figs. 1–5 has the hollow blades **20** spaced peripherally about the rim assembly **24** provided on each of the individual wheels. Each blade is fabricated separately from the other blades.

The wheel structure comprises the central or wheel disk **26** which carries the rim means **24** comprising rim segments positioned and extending peripherally between the blades to sustain the pressure rise from the inlets to the exits of the flow passage. The adjacent segments define sockets **25** having rim opening **29** therebetween contoured to a blade section. See particularly Fig. 5.

The root end **30** of each blade extends radially inward through a said rim opening and is attached or secured to the central disk **26** by means of the flanges **31, 33** on the root end of a stem or sheet metal element **38** and to the other side of the central disk **26** by flanges **32, 34** on the root end of stem or sheet metal element **36**. The upper portions of stems **36, 38** project into the interior of each blade and are secured to the inner surfaces of the blade walls **39***a* and **39***b*. Referring to Figs. 5–7, each blade is positioned at a substantial angle with reference to the central or wheel disk **26** with its leading edge (L.E.) portion extending outwardly in overhanging

relationship to the wheel disk. This portion of the blade receives the upper end of stem **36**, which still conforms to the shape of the inner wall surfaces of the blade, and is joined to the stem by soldering.

The trailing edge (T.E.) portion of the blade projects in the same manner as the leading edge but on the opposite side of disk **26** and receives the upper end of stem **38**, which conforms to the particular shape of the blade trailing edge portion overhanging the disk, and is attached in the same manner as stem **36**.

The lower ends of stems **36** and **38**, beginning approximately at the bottom or root end of the blade, curve inwardly toward the disk **26** with their respective flanges in surface to surface contact with the disk for attachment thereto. The blade skin is comprised of the upper wall **39***a* and the lower wall **39***b* integral across the leading edge (L.E.) of each blade (Fig. 5).

The flanges **31—34** fay the side surface of the disk **26** and are fixed thereto by fused metal preferably a high temperature solder applied after the parts are located relative to each other by spot-welding.

The flanges or other parts of the stem are secured at bonding surfaces thereof to areas of a side surface of the disk. These areas are symmetrically disposed with respect to the root ends of the blades so that the centrifugal forces of each blade are transferred substantially without eccentric moments to a side surface of the disk by shear stress, that is through joints in shear. This arrangement provides light blades and a light disk.

The rim member **24** is comprised of an assembly of individual rim segments, one of the segments being shown in detail in Figs. 8–10. Each segment has a wall **40** with front and rear portions bent downwardly to form front and rear flanges **42** and **43** on each side of the wall **40**. Blade supporting end flanges **46—49** are formed to coincide with the contours of the root ends **30** of blade walls **39***a*, **39***b* and are attached by soldering to the peripherally opposite ends of wall **40**. Specifically, assembled flanges **46**, **47** conform to the flat surface of the blade wall **39***b*, as does the corresponding edge of wall **40**, and flanges **48**, **49** conform to the contour of the cambered blade wall **39***a* and also to their corresponding edge of wall **40**.

In turned tabs or flanges **50—53** are attached to the upper and lower side flanges **42**, **43** while tabs or flanges **54—57** are secured to the wheel disk **26**. By fabricating the rim segments with independent flanges adjacent the blade walls, as opposed to forming flanges by bending the edges of wall **40**, sharp right angle joints are obtained assuring surface to surface bonding of the supporting flanges to the blade walls. Thus the root ends of blades **20** are rigidly contained between adjacent rim segments and associated flange members.

The rim walls **40** may also be soldered to the tabs **59** integral with and turned over at approximately right angles on the periphery of disk **26** for securing the rim means in operative position (see Fig. 5).

The root ends of the blade walls are soldered to the end flanges of the adjacent rim segments. The stems **36—38** of the blades constitutes attachment means for the blades and extend radially inward beyond the rim segment flanges. They are attached by the flanges **31—34** to the central disk **26**.

Since the front and rear flanges **42** and **43** extend a limited distance radially inward all the soldered joints between blades, rim segments, and central disk can be inspected visually. This is one of the great advantages of this assembly.

With the joints exposed to axial view, they may be readily inspected. Also, fusing of the joints can be readily effected through use of tools advancing toward the work along straight lines. This arrangement of the parts adapts the wheel to economical production and is particularly important for the use of machine tools and automatic production machinery.

As shown particularly in Figs. 4, 6 and 7 each blade has the slots **60** and **62** respectively in opposite walls adapting each blade to straddle the central disk **26**. That is the disk extends into the slots when the blade is inserted into its rim opening between the adjacent rim segments. The wheel disk is usually not exactly in the center of the axial length of the rim, since by off-setting it the bending moments from the blades can be reduced.

It will now be clear that by fabricating the hub rings or means and the rim means separately from the disk, the great difficulties and cost of machining a large forging to the desired wheel proportions are eliminated. Where thin disks are machined the tool pressure and the heat from cutting are sources of serious distortions and internal strains which may later cause failure.

The central disks **26** may be stiffened by the radial ribs **63** (Fig. 3 and 4) each fixed to the disk preferably by solder. These ribs are shown with angle cross sections. Where length of life is not a major consideration these ribs may be omitted.

The parts of each wheel are preferably arranged to be welded together at spots **64** so that very few fixtures are required to hold the parts together in the furnace during the soldering operation. The solder may be applied as a paste at the joints or by wires or shims of soldering material held at or in the joints to be soldered.

The front and rear flanges of the rim segments have the seal flanges **66** and **68** to cooperate respectively with the stator inner rings **70** to prevent back flow from one side of the stator to the other. The stator blades of the stator downstream adjacent to wheel **16** are **71**.

The rim segments preferably are assembled and soldered as sub-assemblies and are subsequently placed in position in the wheel.

The disks **26** are joined to the hub rings or hub elements **80** and **82** by fused metal, preferably a strong solder such as silver solder, copper and the like. The rings have keys **84** to locate one ring relative to the other.

The wheels are stacked axially between the end hubs **85** and **86** carrying the shafts **87** and **88**. The wheels are held together by the tie-rods **90** passing through the holes **92** in the projections **94** and through suitable holes in the end hubs.

This inventions refers to compressor rotors for elastic fluids. The bladed wheels making up such rotors have a substantial static pressure rise along the flow passages between blades from leading to trailing edges thereof. To provide for this pressure rise the passages must have closed peripheral surfaces extending between the blades and from the leading to the trailing edges thereof. At the radially inner ends of the passages the rim segments sustain the static pressure while at the outer ends the case performs this function.

Furthermore since there is a substantial pressure rise from front to rear of the wheel the ratio of the hub radius to the blade tip radius is relatively large of the order of 0.5 or more, preferably 0.6 or more, so that the pressure difference between front and rear can be sustained without a return flow at the hub. For a similar reason the blades are peripherally close together, preferably about one chord length or less apart.

When the blades are made hollow of thin sheet metal and thereby of limited weight the blade bases may be omitted and the rim structure can be of limited weight and thickness comparable to the blade wall thickness. The central disk can consequently be made of limited thickness and weight—and all these parts will be able to sustain their own centrifugal load and the centrifugal loads accumulated on them inward from the tips of the blades with sheet metal thicknesses of the order of the blade wall thickness and less than 0.003 times the wheel maximum or tip diameter. Thus the thickness of the wheel disk is less than 0.100 inch for very large wheels. If the disk is made up of axial spaced sub-disks their total thickness can be less than the above values.

The sum of the thicknesses of the sheets comprising a blade should be about 0.002 times the maximum diameter of the wheel or less.

In the preferred form of this invention for a rotor of 36 inches maximum diameter the blades have sheet metal walls of a thickness of about 0.010 inch. The internal stem and rim each has a thickness of about 0.020 inch. The central disk has a thickness of about 0.050.

The blades are subject to both centrifugal loads and fluid-side loads or axial forces as well as vibratory stresses. The wheel disk primarily carries centrifugal loads.

By making the blades hollow of sheet metal which permits the practical use of limited blade wall thickness each blade has a small or limited weight. The saving in weight in the blades reduces the load on the blade fastening and makes feasible the elimination of the blade base and the attachment of the blade directly to the central disk. That is the blade load is not carried in the rim and thence to the central disk. Rather the rim is carried on the blade structure to the central disk. Thus the rim can be of limited thickness and weight. These savings in weight in turn cumulatively reduce the stress on the central disk so that it can be made of such limited thickness that it can be a sheet metal structure.

With these progressive limitations in weight inward along the radii, the parts can be sheet metal pressings or stampings, reducing the weight by about 75% and the costs by a comparable amount.

While I have illustrated specific forms of the invention, it is to be understood that variations may be made therein and that I intend to claim my invention broadly as indicated by the appended claims.

I claim:

1. In combination in an elastic fluid compressor wheel, a disk of sheet metal, a plurality of hollow sheet metal blades spaced peripherally about said disk, each said blade having a sheet metal element extending from the root end thereof to said disk for support thereby against centrifugal stress, said element being fixed to said disk on the side thereof by a solder joint, and a sheet metal rim means extending peripherally between adjacent said blades and from leading to trailing edges thereof to sustain a static pressure rise in fluid flowing rearward between said blades, said rim means having a soldered joint with said blades to sustain said means, said rim means having front and rear flanges extending radially inward to a limited extent to provide for visual inspection of the edges of the soldered joints between said elements and said disk.

2. In combination in an elastic fluid compressor wheel adapted for a flow of a fluid therethrough, a wheel disk of sheet metal, a plurality of hollow sheet metal blades spaced peripherally about said disk, each said blade having an internal sheet metal element fixed in shear to an internal surface of said blade and extending radially inward to said disk, each said element having at its inward end, a flange faying with a side surface of said disk and fixed thereto, and a sheet metal rim means extending peripherally between adjacent said blades and from leading to trailing edges thereof to sustain a static pressure rise in said fluid flowing rearward between said blades, said rim means having radially directed flanges faying with the walls of adjacent said blades and being fixed thereto by fused metal whereby said rim means is sustained against centrifugal force by said blades.

3. In combination in an elastic fluid compressor wheel adapted for a flow of a fluid therethrough, a wheel disk of sheet metal, a plurality of hollow sheet metal blades spaced peripherally about said disk, each said blade having an internal sheet metal element fixed in shear to an internal surface thereof and extending radially inward to said disk, each said element having at its inward end a flange faying with a side surface of said disk and fixed thereto by fused metal, a sheet metal rim means having a rim wall extending peripherally between adjacent said blades and from leading to trailing edges thereof to sustain a static pressure rise in said fluid flowing rearward between said blades, said rim means having side flanges at front and rear sides thereof directed radially inward, each said rim means having at each of its peripherally opposite ends a radially inward directed end flange fixed to the surface of the adjacent said blades, each said end flange having a peripherally directed flange at each of its opposite ends faying with a surface of said side flanges and being fixed thereto by fused metal.

4. In combination in an axial flow elastic fluid compressor wheel, a wheel disk of sheet metal, a plurality of hollow sheet metal blades spaced peripherally about said disk, each said blade having a sheet metal element extending from the root end thereof to said disk and fixed thereto for support thereby against centrifugal stress, and a sheet metal rim segment extending between adjacent said blades and from leading to trailing edges thereof to sustain a static pressure rise in fluid flowing rearward between said blades, said segment including a rim wall whose end surfaces abut the walls of said adjacent blades, and a radially directed end flange at each end of said rim wall fixed thereto, each said end flange faying said wall of said adjacent blade chordwise therealong.

5. In combination in an axial flow elastic fluid compressor, a case, a wheel mounted for rotation in said case, said wheel comprising a separately fabricated disk, a separately fabricated hub means fixed to said disk for the driving thereof, a plurality of axial flow blades peripherally spaced about said disk, each said blade being of hollow sheet metal construction and having a sheet metal element fixed to a side surface of said disk defining a joint at a locality nearer to the perimeter of said disk than to said hub means, and a rim means supported on said disk adjacent to the perimeter thereof and to the ends of said blades and extending from blade to blade and from front to rear of said wheel, said rim means having limited radial extent and being bonded to said side surface at a locality nearer to the perimeter of said disk than to said hub means exposing said joints to view.

6. In combination in an axial flow elastic fluid compressor, a case, a high speed wheel mounted for rotation in said case for impelling fluid with increased density and pressure therethrough, said wheel comprising a central disk of sheet metal, a separately fabricated hub means joined to said disk for the driving of said wheel, a plurality of hollow blades of sheet metal construction fixed to said disk and peripherally spaced thereabout, a rim means secured to said disk and extending from blade to blade adjacent to the root ends thereof and from front to rear of said wheel, and a plurality of peripherally spaced ribs fixed to a side surface of said disk and extending in the general radial direction from a locality close to said hub means to a locality adjacent to said rim means.

7. In combination in an axial flow elastic fluid compressor, a case, a high speed wheel mounted for rotation in said case developing a substantial change in pressure and density of said fluid flowing between the blades of said wheel in the operation thereof, said wheel comprising a separately fabricated central disk having a thickness less than about 0.003 times the wheel maximum diameter and a separately fabricated hub means joined thereon for driving said disk, a rim means carried by said disk adjacent to the perimeter thereof, a plurality of axial flow blades peripherally spaced about said disk and extending radially outward therefrom and axially fore and aft therefrom, said blades extending inward through said rim means and being joined to a side surface of said disk defining joints therewith, said rim means extending from blade to blade and from front to rear of said wheel to sustain said change in pressure, said rim means at an axial end thereof being secured to said disk nearer to the

perimeter thereof than to said hub means, said rim means having limited radial extent exposing said joints to view prior to assembly of said wheel in said compressor.

8. In combination in an axial flow elastic fluid compressor, a case, a high speed wheel mounted for rotation in said case developing a substantial change in pressure and density of said fluid flowing between the blades of said wheel comprising a separately fabricated central disk, a separately fabricated hub means joined to said disk for driving said wheel, a rim means adjacent to the perimeter of said disk and secured thereto, and a set of separately fabricated axial flow blades extending radially outward of said rim means and having a stem portion extending inwardly of said rim means and fixed to a side surface of said disk, there being an individual disk for each set of blades, each said blade being of hollow sheet metal construction including a blade skin formed from a blade sheet integral across a folding line which becomes substantially the leading edge of said blade, said rim means extending from blade to blade and from front to rear of said wheel to sustain said change in pressure.

9. In combination in an axial flow elastic fluid compressor, a case, a wheel mounted for rotation in said case, said wheel comprising a separately fabricated disk, a separately fabricated hub means fixed to said disk for the driving thereof, a plurality of axial flow blades peripherally spaced about said disk, each said blade being of hollow sheet metal construction and having a sheet metal element fixed to a side surface of said disk defining a joint at a locality nearer to the perimeter of said disk than to said hub means, and a rim means supported on said disk adjacent to the perimeter thereof and to the ends of said blades and extending from blade to blade and from front to rear of said wheel, each said sheet metal element being of channel shape with the legs thereof lapping the walls of each said blade and being fixed thereto.

10. A high speed wheel for an axial flow elastic fluid machine comprising a central disk, a plurality of hollow blades spaced peripherally about said disk for reaction with the elastic fluid, said blades having root ends thereon adjacent said disk, an internal stem element secured to an internal surface of each said blade, said stem element also being secured to a side surface of said disk, and rim means extending between adjacent said blades at the root ends thereof and axially of said wheel from the leading to the trailing edges of said blade root ends to confine the flow of fluid axially of said wheel to the radial extent of said blades.

11. In an axial flow elastic fluid machine the combination of a case, a high speed wheel mounted for rotation in said case, said wheel including a central disk, rim means secured to said disk adjacent to the perimeter thereof, a plurality of separate axial flow blades peripherally spaced about said disk extending radially outward therefrom and axially fore and aft therefrom for reaction with the elastic fluid, said blades extending outwardly of said rim means and inwardly therethrough and being joined to said disk, said rim means extending between adjacent said blades and axially of said wheel from the leading to the trailing edges of said blades axially of said wheel, said rim means having a flange extending radially inwardly of said wheel at the same side of said wheel as the joints between said blades and said disk, and said flange being limited in radial extent to expose said joints to visual inspection prior to assembly of said wheel in said elastic fluid.

12. In combination in an axial flow elastic fluid machine, a case, a high speed wheel mounted for rotation in said case for exchanging force with an elastic fluid in the operation of said machine, said wheel comprising a disk, a plurality of axial flow blades secured to said disk and being peripherally spaced about said disk, said wheel in operation developing substantial changes in density and pressure of said fluid flowing between said blades and developing centrifugal forces at the roots of said blades and subjecting said wheel to axial forces, a separately fabricated hub means secured to said disk for the rotation thereof, a rim means secured to said disk and extending from blade to blade adjacent to the root ends thereof and from front to rear of said wheel to sustain said change in pressure, and a plurality of peripherally distributed ribs bonded to a side surface of said disk and extending in the general radial direction inward from a locality adjacent to said rim means over major radial extents of said disk to resist said axial forces.

13. In combination in a wheel for an axial flow elastic fluid machine adapted for rotation about an axis, a wheel central disk, a plurality of blades of hollow interiors spaced peripherally about said disk, each said blade comprising a blade skin and an attachment stem secured within said hollow interior thereof and projecting beyond said skin radially inward toward said axis, said stem extending to said disk and having a peripheral flange connected to the axially outer side surface of said disk and being fixed thereto.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,925,216 February 16, 1960

Edward A. Stalker

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 59, for "opening" read -- openings --; column 4, line 17, for "Fig. 3 and 4" read -- Figs. 3 and 4 --; column 5, line 36, for "a disk" read -- a wheel disk --; line 68, for "adaptd" read -- adapted --.

Signed and sealed this 1st day of November 1960.

(SEAL)

Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents