Sept. 2, 1958 E. A. STALKER 2,850,229

AXIAL FLOW COMPRESSOR CONSTRUCTION

Original Filed Aug. 5, 1948 2 Sheets-Sheet 1

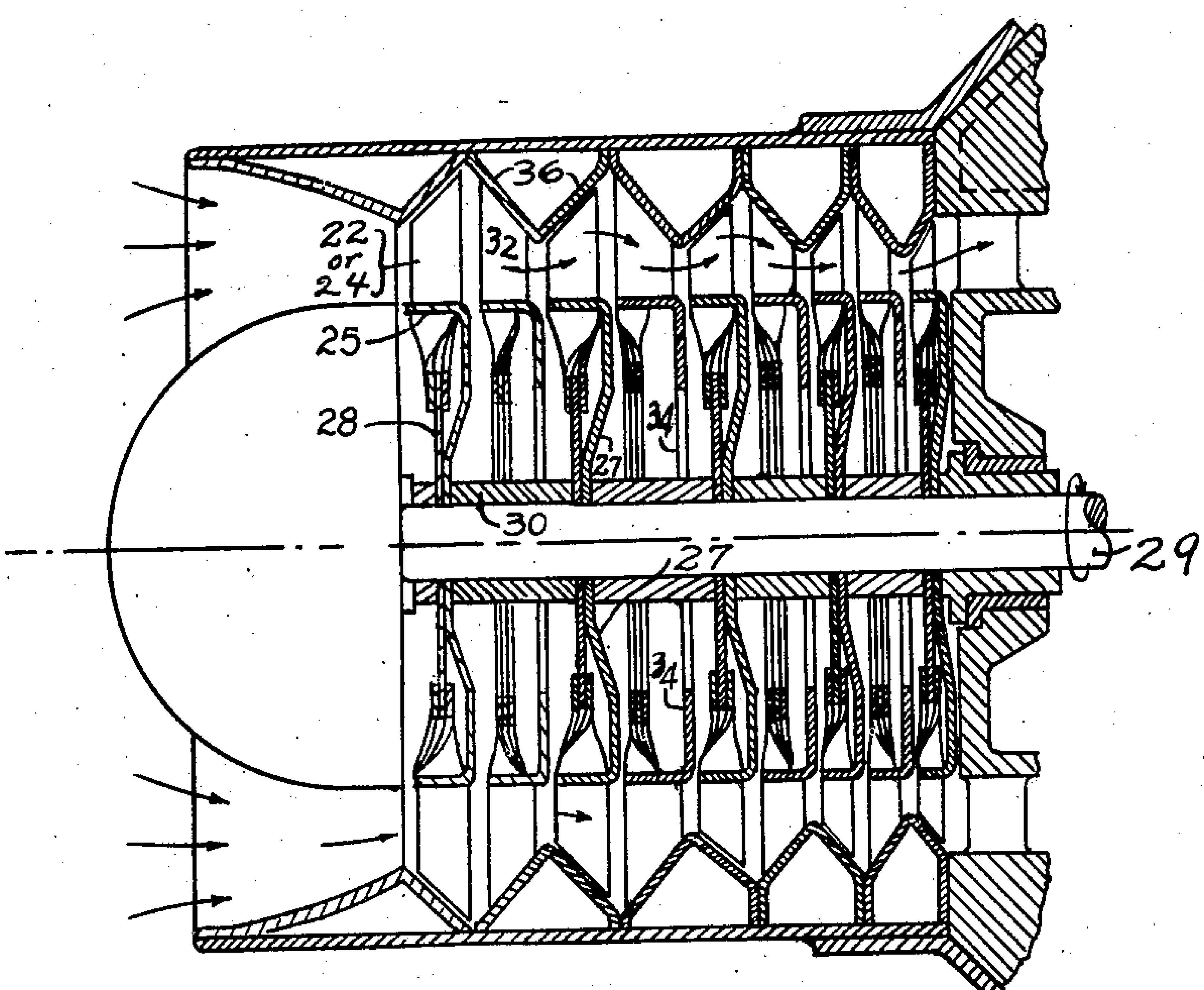

FIG. 1

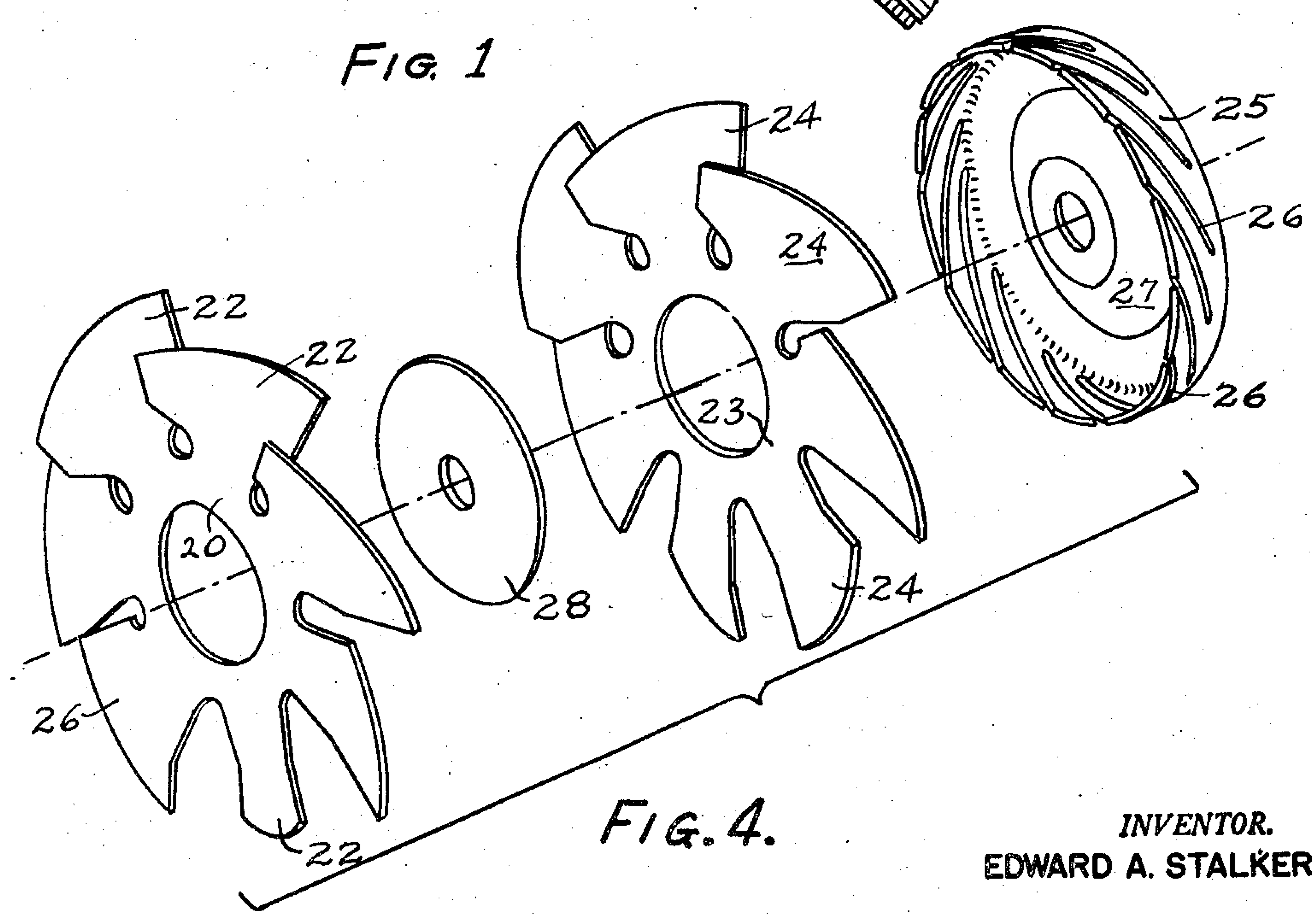

FIG. 4.

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Original Filed Aug. 5, 1948 2 Sheets-Sheet 2

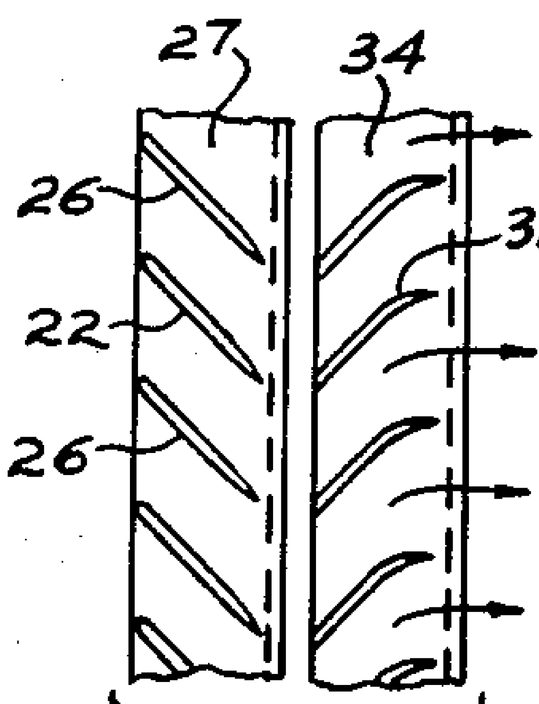

FIG. 2

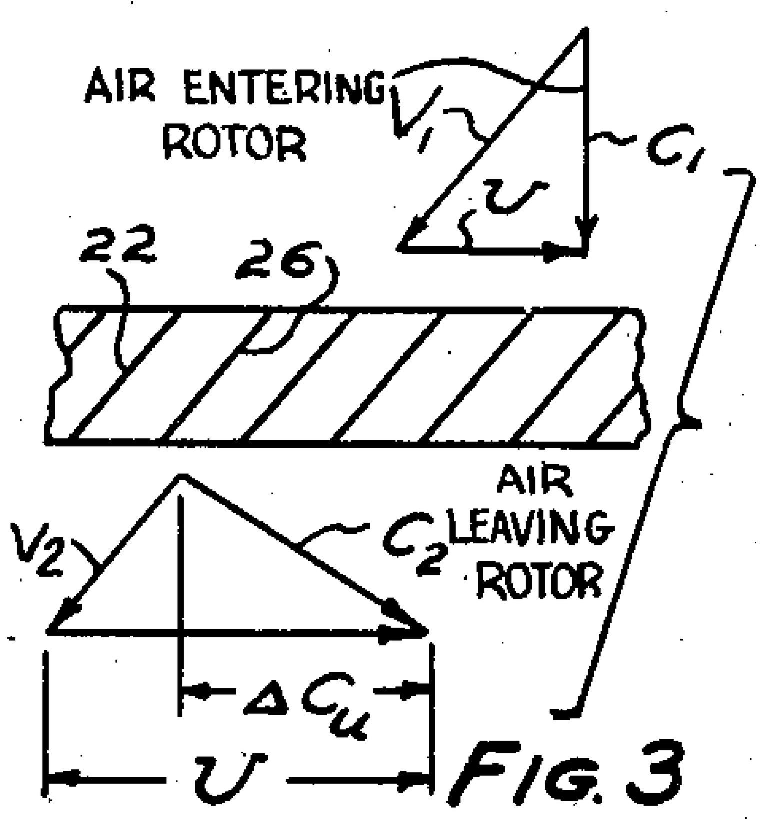

FIG. 3

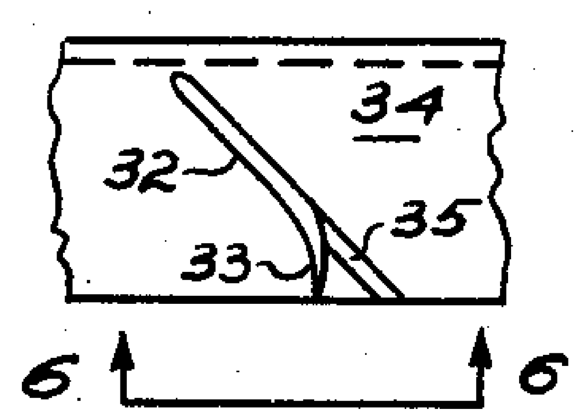

FIG. 5

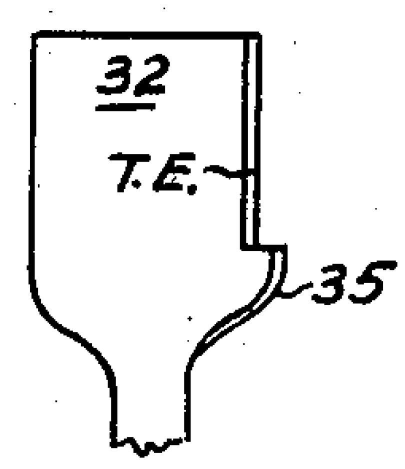

FIG. 6

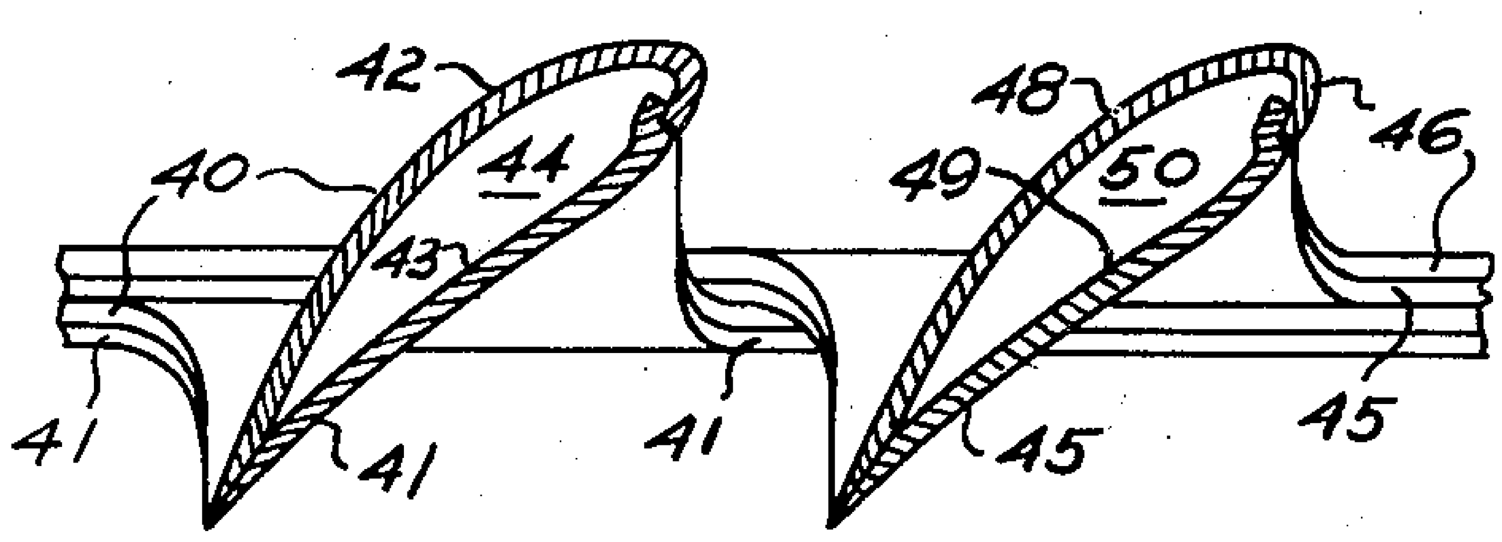

FIG. 7

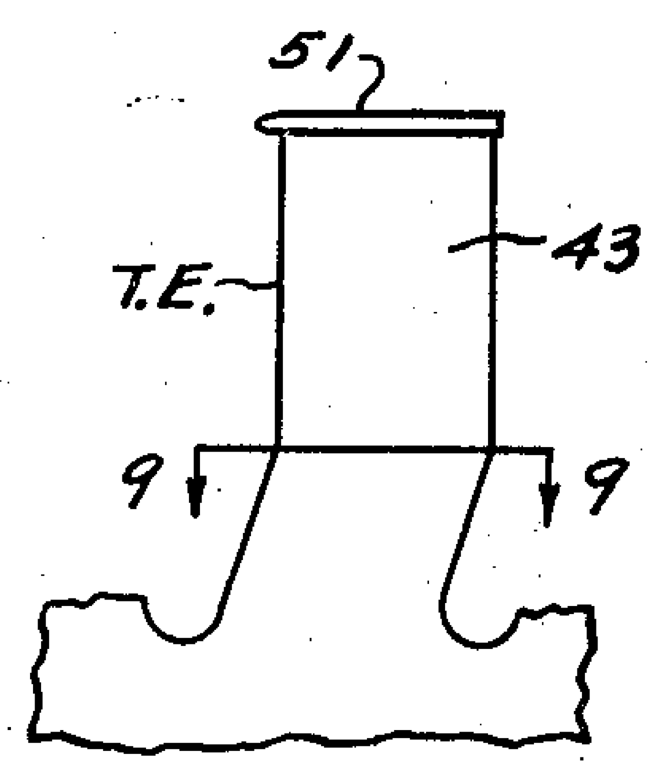

FIG. 10

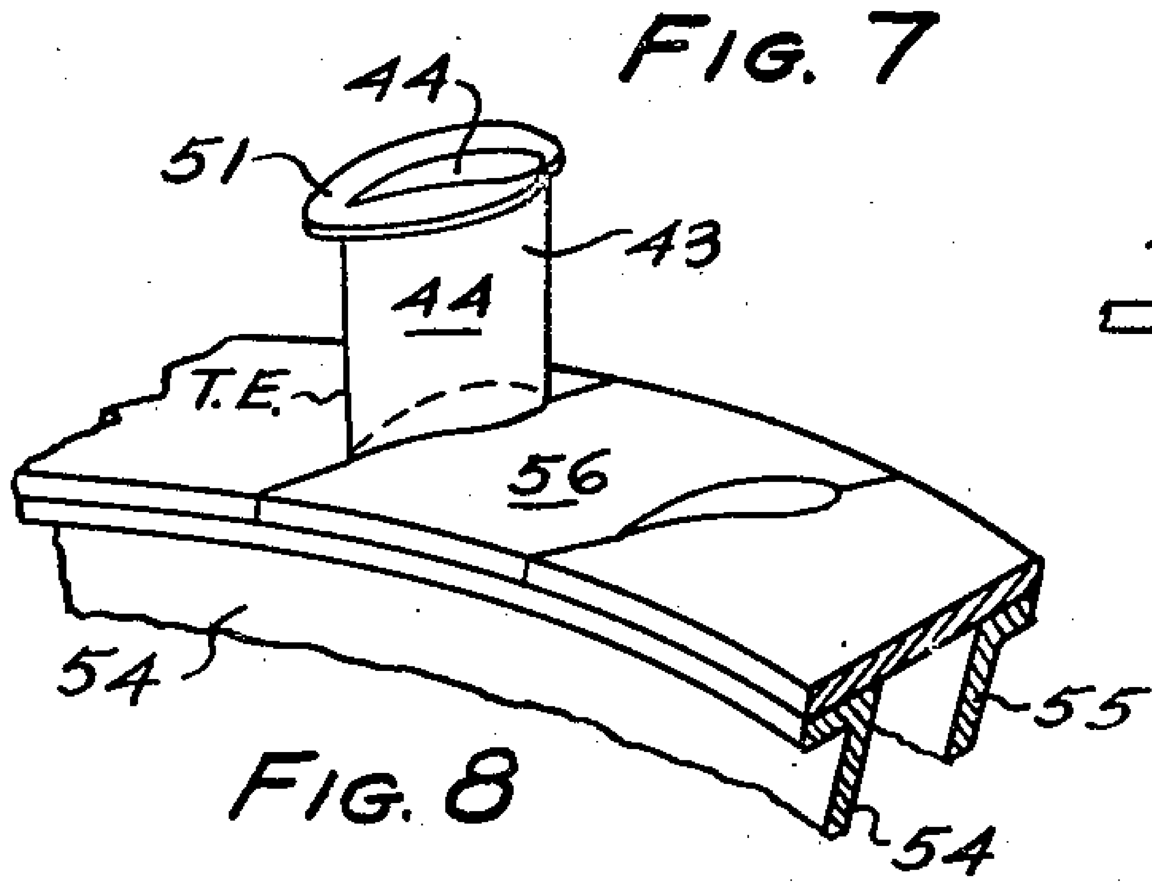

FIG. 8

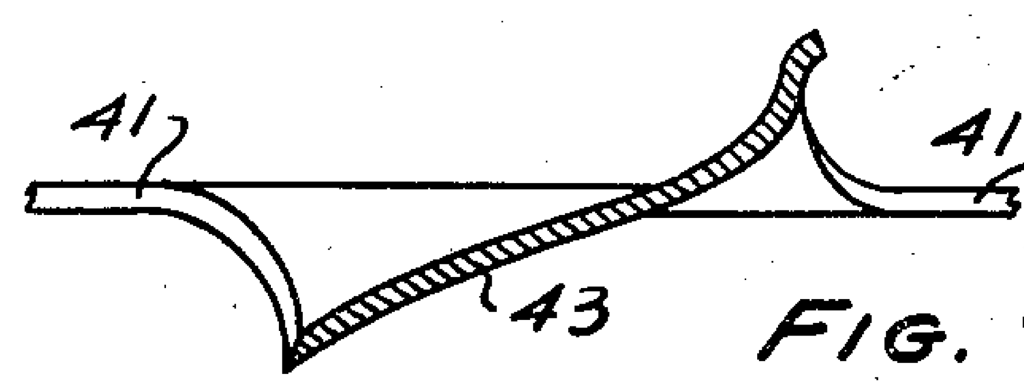

FIG. 9

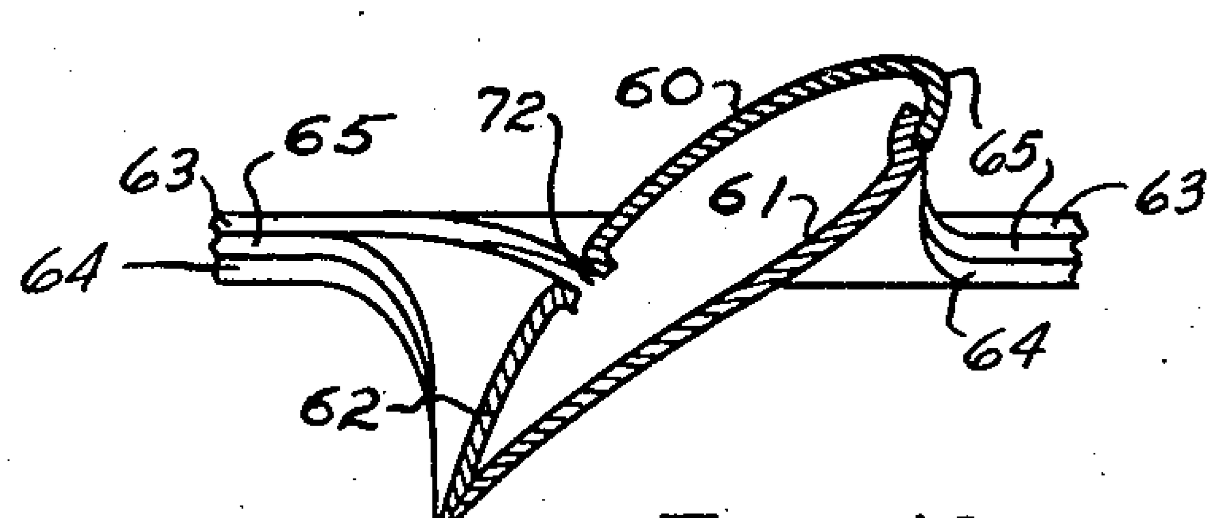

FIG. 12

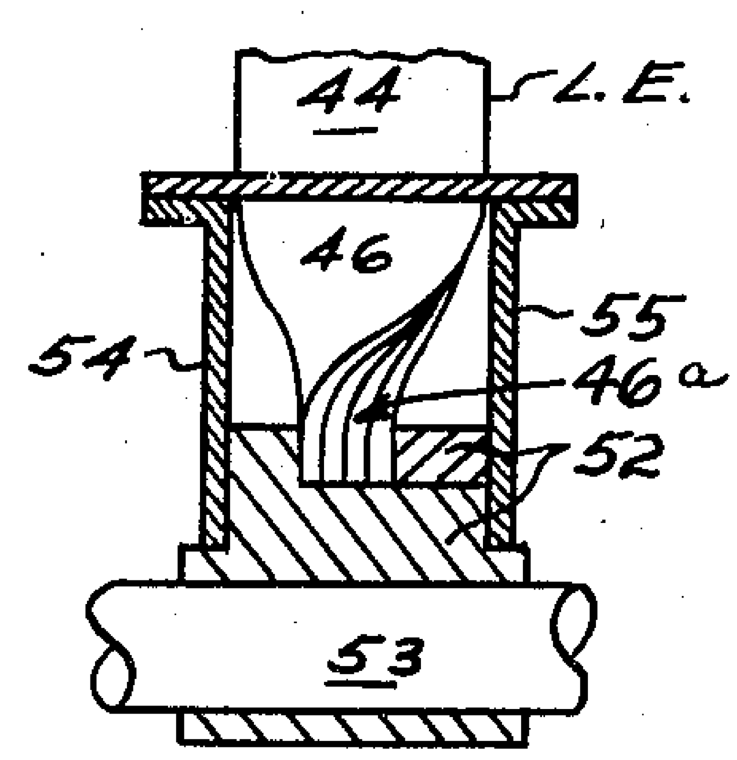

FIG. 11

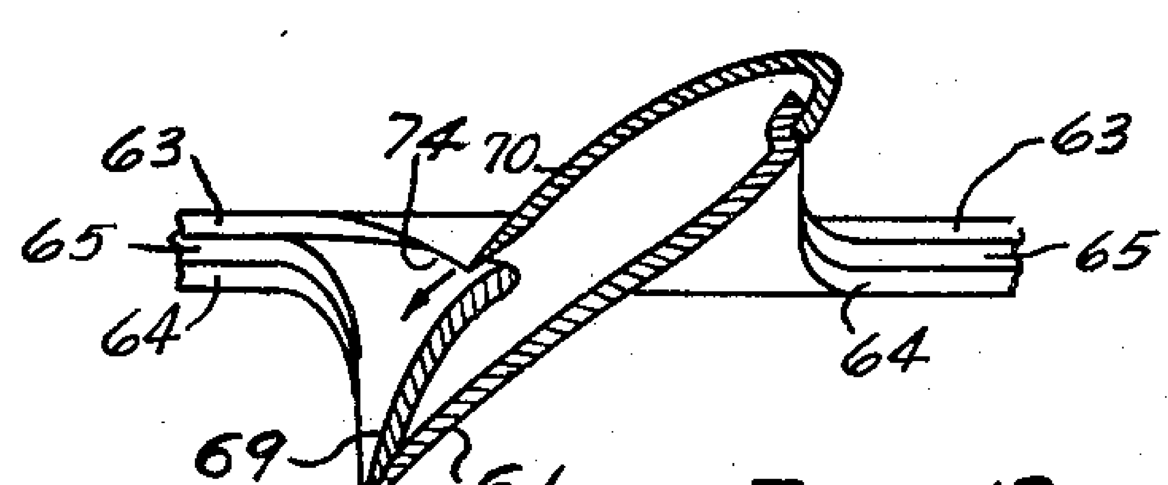

FIG. 13

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AXIAL FLOW COMPRESSOR CONSTRUCTION

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

Original application August 5, 1948, Serial No. 42,565, now Patent No. 2,649,243, dated August 18, 1953. Divided and this application June 23, 1953, Serial No. 363,471

9 Claims. (Cl. 230—134)

My invention relates to compressors and particularly to axial flow compressor construction.

An object of the invention is to provide a type of structure which is cheap to fabricate.

Other objects will appear from the description, drawings and claims.

I accomplish the above objects by the means illustrated in the accompanying drawings in which—

Fig. 1 is an axial section through a radial diffusion compressor of five stages;

Fig. 2 is a fragmentary development of the first rotor and stator of the compressor;

Fig. 3 shows the velocity vectors and a fragmentary development of the rotor;

Fig. 4 is an exploded view to show a method of fabrication;

Fig. 5 is a radial view of a stator blade and a fragment of the inner ring;

Fig. 6 is a view along line **6—6** of the blade only of Fig. 5;

Fig. 7 is a fragmentary radial view of a rotor stage of streamline or hollow blades and their blade plates;

Fig. 8 is a fragmentary perspective view of a rotor blade and ring of Fig. 7;

Fig. 9 is a radial view of a blade part along line **9—9** in Fig. 10, forming the lower surface of a blade, shown on a fragment of the blade plate;

Fig. 10 is a side view of the blade part of Fig. 9;

Fig. 11 is a fragmentary section of the rotor of Fig. 8 taken transverse to the axis of rotation;

Fig. 12 is a radial view of fragments of blade plates contributing parts to a blade having an induction slot; and

Fig. 13 is a radial view of fragments of blade plates contributing parts to a blade having an eduction slot.

This application is a division of copending application Serial No. 42,565 filed August 5, 1948, now Patent No. 2,649,243, issued August 18, 1953, entitled Axial Flow Compressor Construction.

Axial flow compressors require a great many blades. For instance a current eleven stage compressor has 2200 blades. Since each of these blades has airfoil sections of different shape at all chordwise sections along the length which must be machined accurately, their cost is very high. The hub and case must also be machined accurately to receive the blades. The blades are handled individually with the accumulation of large costs.

The present invention provides a construction for the rotors and stators, which does not require individual fabrication and installation of the blades. This type of construction achieves greater lightness and low cost of construction.

The construction as applied to radial diffusion and peripheral diffusion compressors is discussed herein, the latter with respect to both plain and slotted hollow blades.

Reference is made to applications Serial No. 593,631, filed May 14, 1945, now Patent No. 2,648,492, issued August 11, 1953, and Serial No. 687,385, filed July 31, 1946, now Patent No. 2,732,999, which described the radial diffusion principle. The peripheral or conventional axial flow compressor with slotted blades is described in my Patent No. 2,344,835, entitled Pumps, issued March 21, 1944.

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Briefly a radial diffusion compressor is one which expands the fluid radially as it flows between the blades with a general movement in the direction of the axis of rotation.

Fig. 1 shows an axial section through a radial diffusion compressor having five stages. Fig. 2 shows a development of the first rotor and stator. Fig. 3 shows the vector diagram for the rotor. The axial velocity of the fluid entering rotor **22** is C_1, the relative peripheral velocity is U, and the resultant relative velocity is V_1. Due to the radial expansion of the flow in the rotor, the exit velocity V_2 is less than the inlet velocity V_1. The absolute velocity of the air leaving rotor **22** is C_2. The flow has had the whirl velocity ΔC_u added to it, which accounts for the pressure rise of the stage.

It will be observed from Fig. 2 that the series of blades are arranged such that the angle between the forward portion of each blade and the axis of rotation is at least as great as that between the aft portion of the blade and the axis, and that the leading edge of one blade overlaps the trailing edge of the next blade when viewed along the axis of rotation. This overlapping precludes integral stamping or forging the rotor and its blades. Fig. 4 shows how it is possible to fabricate the unit from stampings.

Each blade plate **20** has a plurality of blades **22**. A second blade plate **23** has blades **24** similar to blades **22**.

The cylinder **25**, sometimes called the hub or rim means, has a plurality of slots **26** cut in its wall. These slots have the same pitch angle as the blades **22** and **24**. The cylinder has an inside flange **27** at one end which is not slotted and serves to aid in holding the slotted wall together in the fabrication process.

The blades on each plate are spaced so that they go into alternate slots **26**. With both plates in place all slots are filled with blades. The blades are fused at their roots to the cylinder wall by silver solder, brazing, welding or other suitable means. The blade plates and spacer plate **28** may all be fused together and fixed to hub ring **30** and to the rotor shaft **29**.

It will be readily understood that each plate is insertable in cylinder **25** by forward motion accompanied by a small rotational motion.

Although two plates are shown in the Fig. 4 more plates might be used with proper spacing of the blades thereon.

The stators are formed similarly to the rotors as shown in Figs. 1, 5 and 6. The stator blades are straight along their fore portion **32** and curved along their aft portion **33**. The portion **35** in the slot is straight throughout so that it completely fills the slot. The exposed end of the portion in the slot is flush with the surface of the ring. The trailing edge of the blade is marked T. E. to aid in interpreting Figs. 5 and 6.

Fig. 1 shows that the stator blade **32** for instance has its outer end fixed to the ring **36**. The blade may be inserted in a slot in this ring or be simply fused to it.

The radial diffusion compressor is efficient with plate type blades which are simply rounded at the leading edge and sharpened at the trailing edge.

If it is desired to make the efficiency retain a high value over a wider range of fluid flow per revolution the blades may be given a streamline form. This type of construction is suitable for the rotors of conventional axial flow compressors which are peripheral diffusion machines.

In the streamline blade form, each blade plate carries only a part of a blade. Thus in Figs. 7 to 11 the two plates 40 and 41 carry respectively the upper and lower portions of the blade 44. These two blade supporting plates have their complementing parts 42 and 43 in contact to form the blade 44. These plates provide part of the rotor blades and other blades 50 are supplied by similar plate sets 45 and 46 having respectively the blade parts 48 and 49. The blades formed by the respective plates are interspaced about the periphery of the rotor. This procedure permits the blade parts to be spaced on the respective plates sufficiently to form the parts integral with the central portion of the plate.

The blade parts are scarfed at the trailing edges so that when they are fused together they form a sharp trailing edge for the blade.

The blade parts are joined at the nose by joggling the lower part and fusing the joint preferably by brazing or soldering. Any crevice at the joint may be filled with the solder so the surface will be smooth.

The blade parts at their tip ends have relatively short flanges 51 formed integral therewith. These flanges preferably are about the extent of the fillet radius at their junction with the main surface of the blade part. The fillets have a preferred radius of the order of 5% of the chord length of the blade near the blade tip.

The blade plates such as 41 and 46 are fixed to the hub 52, fixed in turn to the rotor shaft 53. The fixing is preferably accomplished by means of necks such as *46a* (Fig. 11) integral with the blade roots of each blade plate and secured to hub 52 by welding.

The rotor side plates 54 and 55 are flanged and the inner shroud elements 56 are welded or fused to the flanges forming a rim means extending continuously from the leading to the trailing edges of the blades adjacent the root ends thereof. These elements fit snugly to the contour of the blades but are not necessarily fixed to them. The out-turned flanges of the rotor plates facilitate the welding by automatic machine methods.

When a blade with slot 72 is desired three plates may be used to make up the three blade parts 60–62 as shown in Fig. 12. These parts are respectively parts of plates 63–65. It would also be practical to use only two plates and weld the part 62 as an independent piece to the part 61 in spaced relation to part 60 to form the slot 72. The slot may also be an over-lapping type of slot 74 as shown in Fig. 13. Here the part corresponding to 62 is 69 and the fore part 70 corresponds to 60, of Fig. 12.

In this invention the rotors are compressor rotors for increasing the static pressure and density of an elastic fluid. In order to achieve significant change in density with an axial flow compressor each rotor must be operated at a speed high enough to effect a significant change in density, that is a change which in magnitude is outside the usual order of engineering accuracy in the industry. Thus machines are considered to be compressors as distinguished from fans at tip speeds of about 400 feet per second or more. At such a speed the average change in density over the blade length is about 3% which is just about or above the common order of accuracy of measurement of the density. Such compressors are expected also to operate at blade tip speeds close to the velocity of sound. At such speeds the change in pressure is maybe more than 70% or more than 10 pounds per square inch for air inducted at atmospheric pressure.

Since there is a substantial pressure rise from front to rear of a rotor, the ratio of the hub radius to the blade tip radius is relatively large, i. e., of a value of the order of 0.5 and preferably greater, so that the pressure difference between front and rear sides can be sustained without a return flow at the hub such as occurs in a fan. For the same reason the blades are spaced peripherally close together, preferably about one chord length or less apart.

Commonly half to all the pressure rise occurs in the rotor between the leading and trailing edges. To sustain such an increase in pressure along the rotor passages from leading to trailing edges of the blades the hub rim between adjacent blades and from leading to trailing edges must be a fair and continuous surface. Also at all rotative speeds the case must fit closely about the blade tips which are contoured to the cylindrical surface of the case along substantially the whole length of the blade chord.

To diffuse the flow between blades to achieve a pressure rise the flow must follow the blade surfaces without eddies. Accordingly the blades must have rounded leading edges. They must have sharpened trailing edges to be efficient.

Because of the high rotative speeds and the substantial increases in pressure and density of the fluid, positive means of driving the compressor rotor is provided. The shaft 29 is fixed to the hub rings 30 which in turn are fused to the disk 28 and also to the side plate 27. The side plates are fused to the blades at their root ends. Thus the shaft can transmit the relatively high torque required to the disk and side plate and through each to the rotor blades.

Great lightness of the structure is achieved by joining the blades directly to the central disk 28 by fused metal. The blades are each joined by the sheet metal neck or element 23 extending from the blade root to the disk. This element fays the side surface of the disk defining therewith a soldered joint which thus carries its load in shear.

By arranging the joint in this manner, heavy blade bases are eliminated and with them a rim wall which would be thick in the radial direction to accommodate the blade bases. Thus the rotor is relieved of the rim pieces between bases which load up the inner part or unslotted part of the rim without contributing any strength for carrying the peripheral stress in the disk.

Thus by making the blades of sheet metal they are of light weight. By eliminating blade bases and extending light sheet metal structure radially inward to the disk 28 the rim is very light weight and the whole rotor is consequently very light and is strong with all these parts made of thin sheet metal of substantially the same order of thickness as the blade sheet metal.

Since the rotor is to operate at high speed the rim is supported by being fixed to each of the blades or to the root ends thereof, that is at peripherally spaced points, which also makes possible a very light rim wall.

The types of construction described eliminate the individual fabrication of the blades and therefore the necessity of fitting each blade to a rotor or drum. Since the centrifugal force from the weight of the blades and their attachments are the chief load on the rotor a great saving in rotor weight is achieved. This may readily amount to about 40 percent of the rotor weight.

Furthermore since stampings are so cheap to produce and since the individual fabrication and fitting of the blades are eliminated great savings in cost are effected. The present invention therefore has outstanding advantages of lightness and cost. I use the term cylinder to refer to any hub structure having a surface disposed circuitously about the axis of rotation. Cross reference is made to my copending application, Serial No. 38,904, filed July 15, 1948, now Patent No. 2,649,278, issued August 18, 1953, covering similar subject matter.

While I have illustrated a specific form of this invention it is to be understood that I do not intend to limit myself to this exact form but intend to claim my invention broadly as indicated by the appended claims.

What is claimed is:

1. In an axial flow elastic fluid compressor rotor of light weight for operation in an enclosing casing about an axis of rotation, a pair of sheet metal blade plates, each said plate having a plurality of peripherally spaced con-

toured blade parts extending outward of the perimeter thereof with the parts of one plate being formed with contours complementing those of the other said plate, each said part of a said blade plate being juxtaposed in cooperating relation with respect to a said part of the other said blade plate with said contoured parts interfitting and together defining a plurality of hollow axial flow blades each formed with a rounded leading edge and sharp trailing edge adapting said blades to operate at high tip speeds, said blade plates being fixed together, the walls of said blades retaining substantially the same thickness as said blade plates, and rim means between said blades cooperating with said casing in defining passages with inlets and exits between said blades and with the cross sectional width from blade to blade of each said exit being greater than the cross sectional width of each said inlet for increasing the pressure of said fluid at said exits relative to said fluid at said inlets during operation in said casing, said rim means extending peripherally in a general axial direction between adjacent blades and continuously from leading to trailing edges of said blades in effectively closed relation with the root ends thereof to sustain a static pressure increase in said fluid flowing between said blades.

2. In combination in an axial flow elastic fluid compressor rotor of light weight for operation in an enclosing casing about an axis of rotation, a hub for receiving a driving torque, a first pair of sheet metal blade plates, each said plate having a plurality of peripherally spaced contoured blade parts extending outward of the perimeter thereof with the parts of one plate being formed with contours complementing those of the other said plate, each said part of a said blade plate being juxtaposed in cooperating relation with respect to a part of the other said blade plate with said contoured parts interfitting and together defining a plurality of hollow axial flow blades each formed with a rounded leading edge and sharp trailing edge adapting said blades to operate at high tip speeds, a second pair of similar said blade plates forming a plurality of similar said blades, each said pair of blade plates being fixed to said hub with said blades of one pair of plates interdigitating with said blades of the other said pair, said rim means cooperating with said casing in defining passages with inlets and exits between said blades and with the cross sectional width from blade to blade of each said exit being greater than the cross sectional width of each said inlet for increasing the pressure of said fluid at said exits relative to said fluid at said inlets during operation in said casing, said blade plates being fixed to said hub, said rim means extending peripherally in a general axial direction continuously between adjacent blades and from leading to trailing edges of said blades in effectively closed relation with the root ends thereof to sustain a static pressure increase in said fluid flowing between said blades.

3. In an axial flow elastic fluid compressor rotor of light weight for operation in an enclosing casing about an axis of rotation, a rim means secured in said rotor, a plurality of sheet metal blade plates, each said plate having a plurality of peripherally spaced contoured blade parts extending outwardly therefrom, each said part of a said blade plate being juxtaposed in spaced relation with respect to a said part of the other blade plate such that each said pair of parts together define a hollow axial flow blade formed with rounded leading edges and sharp trailing edges and a spanwise slot in the convex surface thereof in communication with the blade interior, said rim means cooperating with said casing in defining passages with inlets and exits between said blades and with the cross sectional width from blade to blade of each said exit being greater than the cross sectional width of each said inlet for increasing the pressure of said fluid at said exits relative to said fluid at said inlets during said operation in said casing, said rim means extending peripherally in a general axial direction continuously between adjacent blades and from leading to trailing edge of said blades in effectively closed relation with the root ends thereof to sustain a static pressure increase in said fluid flowing between said blades.

4. In an axial flow elastic fluid compressor rotor of light weight for operation in an enclosing casing about an axis of rotation, a separately fabricated hub means, a plurality of angularly fixed axial flow hollow blades each defined by a pair of complementing blade plates of sheet metal construction spaced peripherally about said rotor, said blades being formed with rounded leading edges and sharp trailing edges adapting said blades to operate at high tip speeds developing limited centrifugal forces at the root ends of said blades and a substantial change in fluid pressure and density therebetween, a sheet metal rim means extending peripherally in a general axial direction between adjacent said blades and continuously from leading to trailing edges of said blades adjacent but radially outward of the root ends thereof and in effectively closed relation thereto to sustain said pressure increase, side plates fixed to said rim means and to said hub means, and means fixed to said blade plates and extending therefrom inwardly to said hub means to sustain said limited centrifugal forces.

5. In combination in an axial flow elastic fluid machine adapted to interchange energy with an elastic fluid, a rotor hub structure adapted for mounting in a case for rotation about an axis, said structure comprising a plurality of circular plates of sheet metal and a separate hub fixed centrally thereto for transmitting a torque, said plates having contoured upper and lower complementary sheet metal walls juxtaposed in spaced relation defining a plurality of hollow axial flow blades of sheet metal construction, said upper and lower walls of each said blade being fused together spanwise along the nose portion of each said blade and along the trailing edge thereof, said blades being formed integrally with said plates and spaced peripherally thereabout, said hub structure being adapted for rotation developing a substantial variation in pressure in said fluid flowing between said blades, a sheet metal rim wall extending in the general axial direction continuously from the leading to the trailing edges of said blades and from blade to blade adjacent but radially outward of the root ends thereof and in effectively closed relation thereto to sustain said variation in pressure, and means other than said plates securing said rim wall to said hub structure.

6. The combination of claim 5 in which one of the sheet metal blade parts of each blade is formed with a slot in its surface with the walls thereof being properly formed to control the direction of a flow therethrough.

7. In combination in an axial flow elastic fluid machine adapted to interchange energy with an elastic fluid, a rotor hub structure adapted for mounting in a case for rotation about an axis, said structure comprising a separate hub ring means for transmitting a torque and a plurality of circular sheet metal plates substantially thinner than said hub fixed thereto and extending radially outward therefrom, said hub means extending axially outward from opposite sides of said plate, contoured upper and lower sheet metal walls juxtaposed in spaced relation defining a plurality of hollow axial flow blades of sheet metal construction, said upper and lower walls of each said blade being fused together spanwise along the nose portion of each said blade and along the trailing edge thereof, said blades being secured to said plates and spaced peripherally thereabout, said hub structure being adapted for rotation developing a substantial variation in pressure in said fluid flowing between said blades, and a sheet metal rim wall extending in the general axial direction continuously from the leading to the trailing edges of said blades and from blade to blade adjacent but radially outward of the root ends thereof and in effectively

closed relation thereto to sustain said variation in pressure, and sheet metal side plates securing said rim wall to said hub.

8. In an axial flow elastic fluid compressor of light weight, a sheet metal hub structure including a separately fabricated hub adapted for rotation about an axis, means to sustain a substantial pressure difference between the front and rear sides of said structure comprising a plurality of hollow blades each defined by a plurality of complementing blade plates of sheet metal construction carried on said hub and adapted to retain a substantially constant tip diameter while being rotated and contoured at their tips to fit closely to a compressor casing along substantially the entire chord thereof, said blades having rounded leading edges and sharp trailing edges adapting said blades for operation at high tip speeds to accelerate and diffuse efficiently fluid flowing between said blades in the general axial direction, said hub structure including sheet metal plates fused to said hub and integral with said blade plates adjacent the root ends thereof, sheet metal side plates fixed to said hub structure, rim means having parts lapping said side plates for securing said rim means to said hub structure and extending peripherally between blades and in a generally axial direction continuously between the leading and trailing edges of said blades adjacent but radially outward of the root ends thereof and in effectively closed relation therewith to sustain an increase in fluid pressure between said edges, each said blade having a radial length not greater than the maximum radius of said rim means for cooperation in maintaining said pressure difference, and each said blade being fixed to said rim means.

9. In combination in an axial flow elastic fluid compressor rotor of light weight for operation in an enclosing casing about an axis of rotation, a hub for receiving a driving torque, a first pair of sheet metal blade plates, each said plate having a plurality of peripherally spaced

contoured blade parts extending outward of the perimeter thereof with the parts of one plate being formed with contours complementing those of the other said plate, each said part of a said blade plate being juxtaposed in cooperating relation with respect to a part of the other said blade plate with said contoured parts interfitting and together defining a plurality of hollow axial flow blades each formed with a rounded leading edge and sharp trailing edge adapting said blades to operate at high tip speeds, a second pair of similar said blade plates forming a plurality of similar said blades, each said pair of blade plates being fixed to said hub with said blades of one pair of plates interdigitating with said blades of the other said pair, said blades overlapping in axial view, adjacent said blade parts on the same said plate each having chord lengths not greater than the peripheral distance between adjacent said blades on said same plate, said blade plates being fixed to said hub, and rim means extending peripherally in a general axial direction continuously between adjacent blades and from leading to trailing edges of said blades in effectively closed relation with the root ends thereof to sustain a static pressure increase in said fluid flowing between said blades.

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