

**May 26, 1959**

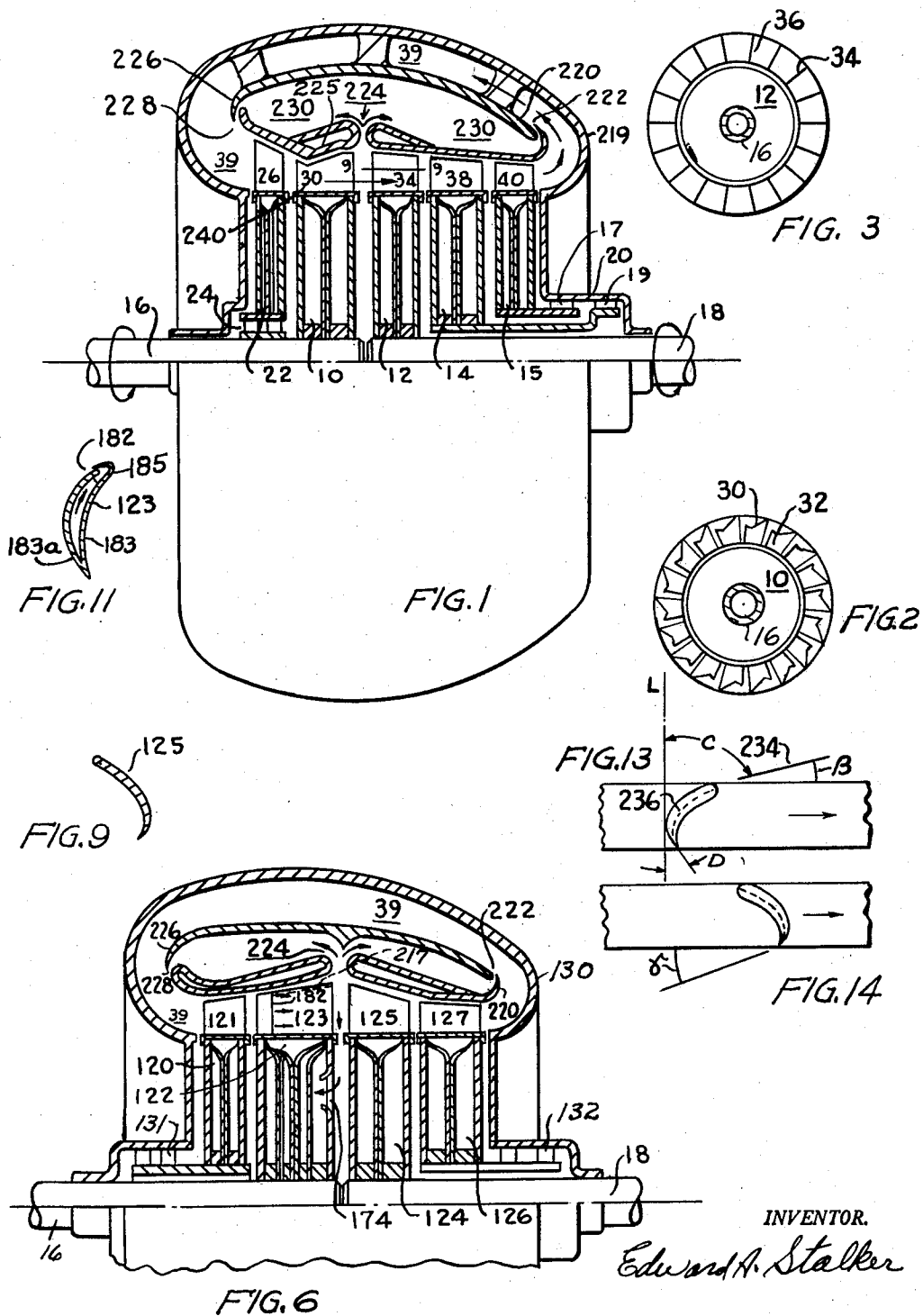
**E. A. STALKER**

**2,887,957**

## BLADED AXIAL FLOW PUMP CONSTRUCTION

Original Filed March 12, 1949

4 Sheets-Sheet 1



May 26, 1959

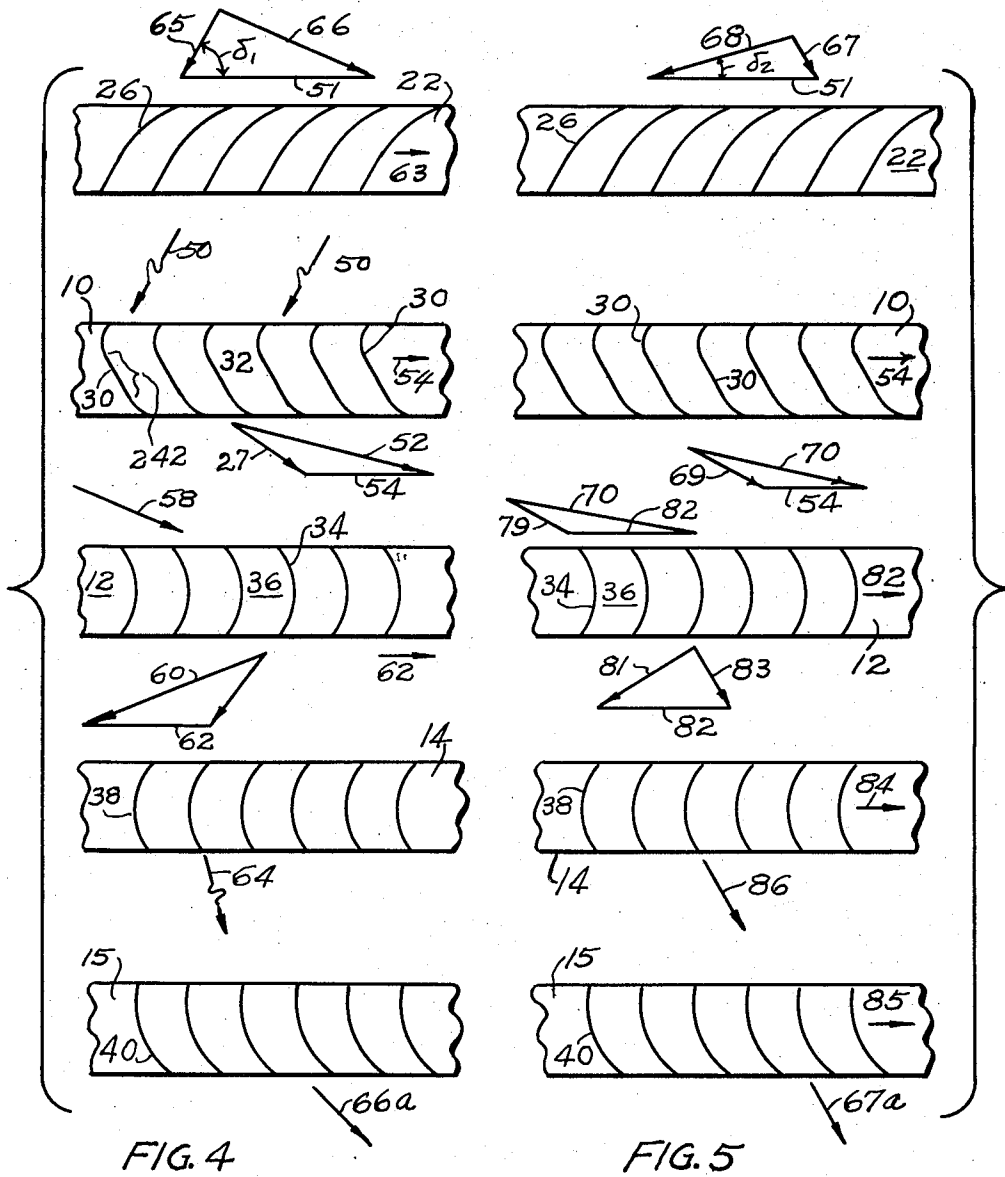
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BLADED AXIAL FLOW PUMP CONSTRUCTION

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4 Sheets-Sheet 2



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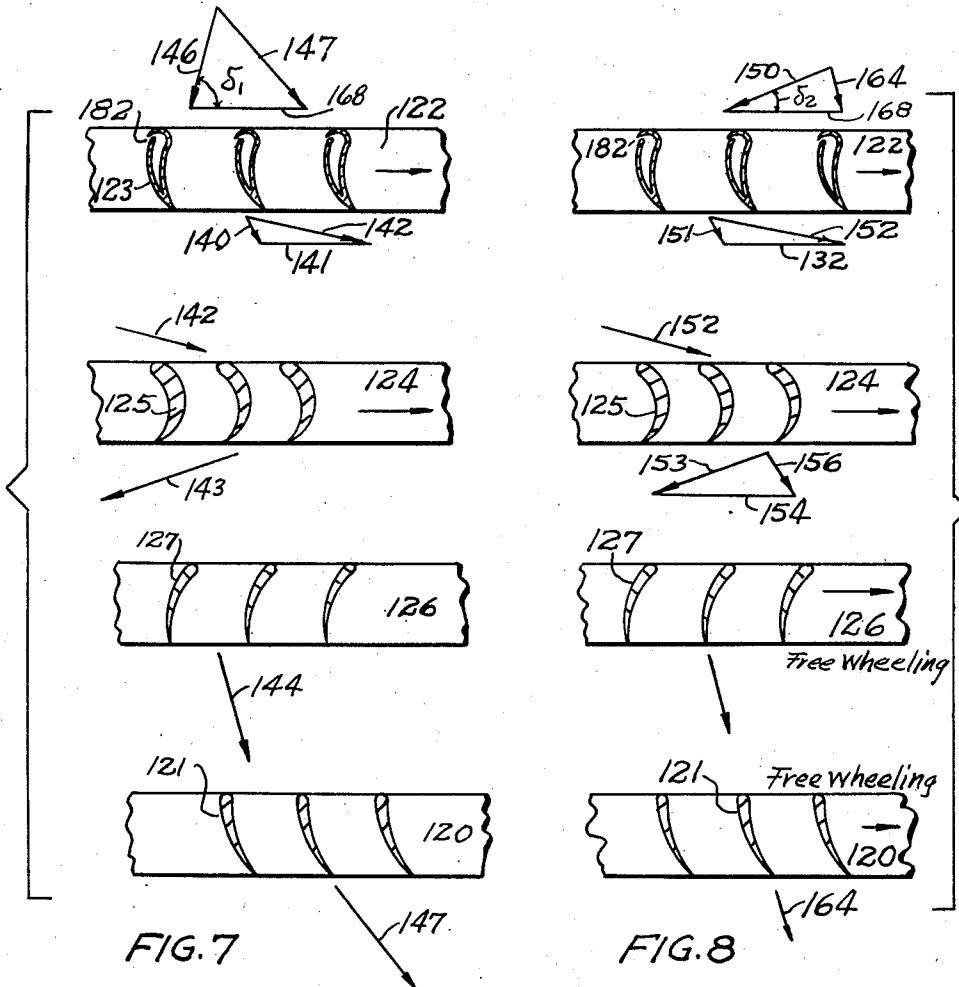
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4 Sheets-Sheet 3



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## BLADED AXIAL FLOW PUMP CONSTRUCTION

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4 Sheets-Sheet 4

Edward A. Stalker

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2,887,957

## BLADED AXIAL FLOW PUMP CONSTRUCTION

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Application May 29, 1953, Serial No. 358,252

17 Claims. (Cl. 103—89)

My invention relates to axial flow pumps and particularly to their bladed axial flow wheels or rotors.

This application comprises material divided out of my copending application Serial No. 81,104 filed March 12, 1949, now Patent No. 2,678,537 issued May 18, 1954. This application is directed to the structure of an axial flow bladed wheel for pumping fluid, particularly a wheel of sheet metal construction.

Cross reference is made to my copending application Serial No. 42,565 filed August 5, 1948, now Patent No. 2,649,243 issued August 18, 1953.

An object of my invention is to provide a pump having sheet metal bladed wheels which are economical to fabricate.

Another object is to provide a wheel having slotted blades in communication with the wheel hub.

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

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

Fig. 1 is a part axial section through a fluid transmission;

Fig. 2 is a front view of the pump rotor in Fig. 1;

Fig. 3 is a front view of the turbine rotor in Fig. 1;

Fig. 4 is a development of the wheel together with its flow vectors for the case of the turbine wheel not rotating;

Fig. 5 is similar to Fig. 4 except that the turbine wheel is rotating at high speed;

Fig. 6 is a part axial section through an alternate transmission;

Fig. 7 is a fragmentary development of the blading of the transmission of Fig. 6 with the turbine wheel stationary;

Fig. 8 is a fragmentary development of the blading of Fig. 6 with the turbine wheel turning at high speed and substantially no torque magnification;

Fig. 9 is a section through the turbine blade on line 9—9 of Fig. 1;

Fig. 10 is a perspective view of a pump rotor partly in section;

Fig. 11 is a section through the pump blade on line 11—11 of Fig. 12;

Fig. 12 is a perspective view of the rotor with slotted blades, with part of the rotor in section;

Fig. 13 is a diagram defining the inlet angle for the flow relative to a wheel;

Fig. 14 is a diagram defining the exit angle for the flow relative to the wheel;

Fig. 15 is a fragmentary development of the blading of an auxiliary pump rotor and pump wheel; and

Fig. 16 is a fragmentary section of an alternate auxiliary pump rotor and pump wheel shown in relation to a fragment of a transmission case.

Referring to the drawings the pump wheel is 10, the turbine wheel is 12, the first reaction wheel is 14 and the second reaction wheel is 15. The pump wheel is fixed to the power input or driving shaft or hub 16 while

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the turbine wheel is fixed to the output or driven shaft 18. The reaction wheels are mounted on free wheeling units 17 and 19 on the stationary structure 20. The secondary pump wheel or rotor 22 is mounted on the pump shaft 16 by means of the free wheeling device 24 which permits the rotor to over run the shaft but not to lag behind the shaft. The rotor blades are 26, spaced about the rotor perimeter.

The pump wheel 10 has a plurality of blades 30 spaced about its perimeter forming a plurality of flow passages 32 between adjacent blades. See Figure 2.

These passages increase in radial depth and transverse cross sectional area rearward along a substantial portion of each passage.

The turbine wheel, Figs. 1 and 3, has a plurality of blades 34 spaced about its periphery forming a plurality of flow passages 36 between adjacent blades. These passages decrease in cross sectional area from inlet to exit and preferably the blades are reduced in radial length from inlet to exit as shown.

The reaction wheel 14 and 15 preferably have at their periphery blades 38 and 40 which reduce in radial length from the front to the rear of the wheel.

All these wheels are axial flow bladed rotors.

In an axial flow wheel the leading and trailing edges of the blades extend radially and receive the fluid flow transversely thereacross. The blades define wheel flow passages therebetween each extending from an inlet at the front to an exit at the rear of the wheel for discharging fluid rearward in the general axial direction.

When the pump wheel is rotated it delivers fluid through the passage between its blades to the passage between the blades of the turbine and the reaction wheels. The fluid is returned to the inlet of the pump rotor by way of the annular conduit 39 (which with the wheels constitutes a conduit means) extending about the periphery of the transmission.

The flow of fluid from the pump exerts a torque about the axis of the shafts 16 and 18. The wheels 14 and 15 and the blades 26 of the rotor 22 direct the fluid on to the blades of the pump wheel to aid the rotation and hence magnify the value of the torque which is applied to the turbine as compared to the pump shaft torque.

As the speed of the pump wheel increases it applies sufficient torque to turn the turbine wheel and drive the driven shaft.

The relation of the flow to the respective wheels is best described in conjunction with a development of the blading and their vector diagrams.

In Figure 4 is shown a fragmentary development of the blading of the wheels when the turbine wheel is not turning and its torque is a maximum.

The fluid approaches the pump rotor 10 in the direction 50 and is turned by the rotor blades to the direction given by vector 52 which is the resultant or absolute velocity vector. The rotor blades have the peripheral speed 54 at about mid-point of their spans.

The fluid approaches the turbine blades 12 along vector 58 which has the same magnitude and direction as vector 52. The turbine blades turn this fluid to the direction 60. As a consequence the turbine has exerted upon it a torque tending to turn it in the direction 62. The fluid next enters reaction wheel or member 14 which is stationary. It deflects the fluid along vector 64. The fluid is deflected further by reaction wheel or member 15 to the direction of vector 66a.

The fluid leaves the member 15 and flows through the annular conduit 39 to the front end of the transmission or torque converter. In Figure 4 the vector 66a changes to vector 66 of reduced velocity just ahead or upstream from the secondary pump rotor 22. This rotor will free wheel in the direction 63 because the resultant of vector 66

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and 63 attacks the blade at a sufficiently negative angle, that is along vector 65. Since the rotor rotates freely ahead of the pump wheel it will not significantly change the direction of the flow approaching the pump wheel 10. Therefore vectors 65 and 50 are substantially parallel.

Since the vector 66 represents spin in the fluid in the direction of rotation of the pump wheel the pump has to exert a smaller torque on the fluid than is received by the turbine. There is therefore a conversion or magnification of the pump torque.

In Fig. 5 which represents the conditions when the turbine wheel is rotating, i.e. travelling toward the right at high speed, the secondary pump rotor 22 tends to lag behind pump wheel 10 and becomes locked to it through the agency of the free wheeling device.

The fluid approaches the pump rotor as vector 67 which combined with the peripheral velocity 51 gives the absolute vector 68. The fluid leaves the pump wheel 10 in the relative direction 69 and the absolute direction 70.

The fluid enters the turbine 12 as vector 79, the resultant of 70 and the peripheral vector 82. It leaves the turbine along line 81 giving the absolute velocity vector 83. The fluid passes through the free wheeling wheels 14 and 15 without significant change in direction which are indicated respectively as 86 and 67a. Due to variation in the cross section of passage 39 vector 67a becomes 67 just ahead of rotor 22.

The fluid can enter the pump wheel 10 with low shock losses for all conditions of operation because of the ability of the secondary rotor to free wheel. This is well known in the art.

The blades of pump wheel 10 are bent forward at their aft ends so that the absolute velocity vector 52 has a large magnitude due to the additions of vectors 27 and 54, and also a very small angle with the transverse plane, that is, the plane of rotation. With such values the angle of approach varies very little from the condition where the turbine wheel is stopped as in Fig. 4 to the condition where the turbine wheel is rotating at high speed as in Fig. 5. This is an important feature since not only are the shock losses reduced, but also great economies in fabrication can be had from sheet metal fabrication which can be used if the angular variation is small.

The inlet area of the secondary pump wheel 22 is shown somewhat larger than the exit area of the turbine wheel. Also the peripheral velocity component of the vector 67 is about equal to the peripheral component of vector 83. Also vector 83 has almost the same magnitude and direction as the vector 67. If they were equal and the secondary pump, the pump wheel and the turbine wheel all rotated together as a rigid rotor, there would be no pumping action. Since this condition is almost attained the pumping action is very small which accounts for the low value of the axial velocity components of vectors 67 and 83 compared to the axial magnitudes in Fig. 4.

It is desirable for the design condition of operation that the rate of flow in the transmission be small to avoid fluid energy losses. Since the losses are proportional to the square of the fluid velocity, a low value of the latter makes for very low losses.

At the design condition when no torque magnification is desired, the turbine speed approaches closely the speed of the pump.

Fluid in passing through the pump wheel 10 experiences a static pressure rise which makes vector 27 small as compared to vector 50. The increasing radial depth giving a greater exit area than inlet area to the passages between blades causes the static pressure rise. This static pressure is converted to velocity in the turbine resulting in vector 60 being larger than 58 Fig. 4. Thus when the secondary pump rotor is free wheeling the pump wheel 10 gives more pumping action than when the secondary rotor is fixed to the shaft and rotating at the same velocity

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as the pump wheel. Or in other words when the secondary rotor rotates with the pump wheel the pumping action is reduced because the exits of the pump passages are then smaller than the inlets. This reduction is desirable because at high turbine speeds a low fluid flow is desirable.

It is to be noted with respect to Figs. 1, 4 and 5 that the flow cross section just ahead of rotor 22 is larger than that just aft of rotor 15. This provides a reduction in axial velocity without altering the peripheral component. Thus in Fig. 4 for instance the peripheral velocity component of vector 66 is equal to that of 66a. The use of these relative sizes of flow cross sectional areas brings the angles of approach nearer to equality for a wide range of turbine speeds relative to the pump. This is readily seen by considering that the inlet cross section becomes very large. Then the axial velocity would approach zero and the approach vectors 65 and 68 in Figs. 4 and 5 would both be almost parallel to the the plane of rotation.

In the general case, the condition for no pumping action by the combined pumps and turbine wheels is that the blade angles, and inlet and exit areas of the pump and turbine wheels are rotated at the same speed, no increment of peripheral component of velocity will be added to the fluid in passing through said wheels.

In another form of the invention as shown in Fig. 6 the secondary pump rotor is omitted and a reaction wheel 120 is positioned ahead of the pump wheel 122. This wheel 122 with its blades 123 is followed by a turbine wheel 124 and a reaction wheel 126.

The turbine 124 and reaction wheels are preferably made with decreasing radial depth from inlet to exit of their passages between blades. This will accelerate the flow through them and keep fluid losses to a minimum by preventing separation of the fluid from the curved surfaces.

The reaction wheels 120 and 126 are mounted on the case 130 by free wheeling units 131 and 132 respectively. They lock against turning counter to the direction of rotation of the turbine. Pump wheel 122 is fixed to shaft 16 and turbine wheel 124 is fixed to shaft 18 as in the form shown in Fig. 1.

In order that the pump blades can accommodate a relatively wide range of angles of approach of the fluid, they are each provided with a slot in their surface through which a flow is induced to compel the main flow to follow the blade surface.

An examination of the vector diagrams shown relative to the blade developments in Fig. 7 discloses graphically the reason for use of the slots.

In Fig. 7 the two reaction wheels 120 and 126 are stationary. The flow enters pump wheel 122 along vector 146 and leaves the pump wheel along vector 140 which combined with the peripheral vector 141 gives the absolute vector 142 which relates the flow to the turbine wheel assumed to be stationary. The flow vectors 143 and 144 have positive angles of attack relative to the blades 127 and 121 so these wheels are made stationary by the locking of the free wheeling devices. The vector of the flow leaving reaction wheel 120 is 147. This vector combined with the peripheral vector of the pump gives the approach vector 146.

The approach vector to the pump in Fig. 8, representing the conditions where the turbine wheel is rotating fast, is 150 and it is clear that the angle  $\alpha_1$  of Fig. 7 is considerably larger than the angle  $\alpha_2$  of Fig. 8.

The flow approaches the turbine blades along vector 152 and leaves along vector 153 which combined with the peripheral vector 154 gives the absolute vector 156. Since the wheels 126 and 120 are now free wheeling because of the negative approach of the fluid, the vectors 162 and 164 are almost parallel. Vector 164 is repeated just ahead of the pump and in combination with

the peripheral vector 168 for the pump gives the approach vector 150 as previously referred to.

The blades of the turbine and reaction wheels are simple curved sheets with rounded leading edges and sharpened trailing edges as shown in Fig. 9. Fig. 10 shows how reaction wheel 126 is made from simple sheet metal stampings. All the blades are stamped integral with their central plate portion. Alternate blades are on one blade plate 129 and the interdigitating blades are on the other blade plate 131. Since none of the blades of any one plate overlap each other, each plate with its blades can be stamped in one operation. The blade plates, side disks 169, rim segments 170 and the hub means comprised of hub members 171 and 172 are bonded by furnace brazing to form the complete wheel. It may be fixed to the shaft 16 by brazing also.

Fig. 11 shows a section of the pump blade 123 whose discharge slot 182 receives a flow of fluid from the openings 184 in the rotor disk as shown in Fig. 12. The wheel plates 186 and 188 from which one group of the blades are formed are spaced apart by spacers 190 so that fluid can reach the interiors of the blades at their root ends. The other group of blades of this same wheel are formed from wheel plates 192 and 194 in a similar manner and the blades of one group interdigitate with the blades of the other group to provide the rotor with its full set of blades.

The blades 123 are defined by wall means including the lower wall means 183 which extends substantially continuously from the trailing edge of each blade around the blade leading edge defining the slot 182 with the upper rear wall 183a. The upper and lower walls are secured together at the roots and tips and by the bridging elements 185 spaced along the slot.

The blade surface with its slot 182 constitutes a surface opening means for controlling the boundary layer of fluid on the surface.

It is commonly understood in engineering and industry that sheet metal construction is limited to sheets whose planar dimensions are large in comparison to their thicknesses for thicknesses less than about  $\frac{3}{16}$  of an inch.

In sheet metal construction the parts are formed from the virgin sheets by pressing them in dies or over forms without greatly changing the thickness of the sheet such as is ordinarily accomplished by machining or striking with hammers or forging devices.

The hub structure includes the sheet metal side plates 210, rim means comprised of the rim segments 212 stamped from sheet metal, and suitable hub members such as 190 and 218. These plates and the blade or wheel plates are bonded to the hub means comprising hub members 216 and 218 which are fixed to the shaft 16. The rim segments have the front and rear side flanges 213 and the radially directed hole flanges 214 in rim walls 215 shaped to fit the blade chordwise contour at the roots of the blades. The blades, segments and plates are preferably bonded by a furnace brazing process.

The rim wall extends integrally or connectedly from the front to the rear of the rim means so that the static pressure of the pumped fluid can be sustained and so that the centrifugal force of the rim wall due to its high speed rotation can be transmitted from its central portions to its supporting connections. Preferably the rim wall is also supported by a flange 214 or like structure to support the rim wall.

The centrifugal force on each blade is sustained by the sheet metal connecting elements 189 integral with the root ends of the blades and with the central portion 187 of each blade supporting plates 186, 188, 192, and 194 which are in turn secured to the hub members 216 and 218.

In the axial flow pump wheel of this invention the structure is adapted to sheet metal construction capable of sustaining the centrifugal loads by making the blades

hollow with thin sheet metal walls which limit their weights and hence the centrifugal loads on the inward structure. Then by eliminating a blade base the wheel hub rim may be of limited thickness and weight which in turn limits further the centrifugal load on the inward structure. If both the blade structure and the rim structure are of limited thicknesses and weights, the wheel plates such as 186 and 210 can be of limited thicknesses of the same order as the blade wall thickness and yet be able to sustain the centrifugal loads.

This leads not only to a very light structure but also to a very economical structure not only because weight is saved but also because a stamping of sheet metal and sheet metal parts are the cheapest structures. This invention by accumulating the weight savings from the blade tips inward provides for savings increasing or mounting by a sort of exponential function of the distance inward from the blade tips inward and thereby making practical and feasible a sheet metal rotor for high tip speeds and high fluid loads.

The case 219 houses the wheels and provides the annular conduit 39 to conduct the flow back to the front of the transmission. It also provides a chamber for serving fluid to control the flow on the conduit walls.

The inner wall 220 of the bend in the conduit 39 is provided with a slot 222 to induce the fluid to follow the wall without separation. This slot receives fluid from the peripheral opening 224 served with fluid pressure from pump wheel 10. The wall 226 has the slot 228 for the same purpose and receives fluid under pressure from the annular chamber 230.

The angle between the tangent 234 to the mean line 236 of the blade section at the leading edges and the plane of rotation is called the entrance or inlet angle  $\beta$ . A tangent at the trailing edge defines with the plane of rotation a discharge angle  $\gamma$ . These are shown in Figs. 13 and 14 respectively.

It will be seen in Figure 5 that the discharge angle for the turbine blades is substantially equal to the inlet angle for the pump blades but of opposite sign. That is one discharges in the opposite direction to the other.

The proper relation between the discharge angles is important so that the rate of flow in the transmission circuit tends to reduce to a very small value as the speed of rotation of the turbine approaches the speed of the pump wheel as previously discussed.

The wheel of the pump is adapted to operate with relatively high pressures acting both radially and peripherally and with substantial change in fluid pressure between the leading and trailing edges of the blades. Fig. 13 shows a fragment of a compressor rotor whose blades 236 have the nose portions at a greater angle C to the axis than the angle D of the rear portions to produce substantial pumping action on the fluid.

The wall 225 of the case means 219 serves to sustain the radial pressures and by enclosing the wheel closely about the blade tips is adapted to sustain the pressure difference between the front and rear sides of the wheel.

The axial flow pump wheel is a special type. It is characterized by each passage between blades having a greater radial depth at inlet than at exit. In other words the annular exit area of the wheel is substantially larger than the annular inlet area of the wheel. Preferably the radial depth at exit is from 2 to 3 times the radial depth at the inlet to each passage between blades.

The pumping action of this type of rotor depends on the increasing pressure arising from the slowing down of the fluid in the rotor passage after the manner of Bernoulli's formula. Thus the fluid reaches the pump exit with very little axial velocity. The fluid leaving the rotor has a high static pressure and in addition is given a spin in the direction of rotation. This type of pumping action is described in more detail

in my copending application Serial No. 687,385 filed July 31, 1946, now Patent No. 2,732,999. Another advantage of this type of pump wheel is that it can efficiently accommodate a wider range of angle of approach of the fluid than the conventional axial flow type even with unslotted blades.

The pump wheel as shown in Fig. 1 has a converging portion succeeded by a diverging portion thereby defining a throat 240. Since the static pressure of the fluid will be low at the throat the fluid can be made to follow about a nose or leading edge curvature of the blade of small radius without separation from the blade surface along the inlet portion of the blade. In other words the fluid is flowing into a region of low pressure and can therefore accomplish a sharper turn without shock losses.

It will also be noted that the main curve of the blade is located just ahead of the throat 240 so that the flow will be accelerated while making the turn along the curved inlet portion. Following the curve the blade has a substantially straight portion 242, Fig. 4, along the length of the passage where it is expanding in radial depth. When the blade is again curved the passage assumes a substantially uniform radial depth so that the turn of the fluid along the aft end of the blade, the curved aft portion, is not accomplished against an increasing static pressure. Instead of a constant radial depth, a slightly decreasing depth might also be employed.

The form of the blade and passage provides for turning the fluid through a great angle without separation and the resulting energy losses. The pump wheel of Fig. 6 may also be made with a like arrangement of throat and curvatures.

I have used the term wheel to indicate either a rotor or a stator. The fluid transmissions described could if desired have their reaction wheel fixed. This might be done where efficiency is not important but initial cost is.

The wheels 123 Fig. 11 are pumping wheels with pumping passages between the blades 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 thereof and said axis. The angles are to be measured with respect to tangents to the mean (camber) line 236, Figs. 13 and 14 of a blade section at localities close to the leading and trailing edges.

The secondary pump rotor 22 is used in Fig. 1 primarily to receive the fluid into the pump at the small approach angle  $\delta_2$  instead of the angle  $\delta_1$  for which the pump wheel 10 is designed. There is however another advantage in using the secondary pump rotor where the radial depth of the rotor passages decreases from inlet to exit, even when the presence of the secondary pump rotor does not change the entrance angles, as shown in Fig. 15. Here the blades 250 have the same angularity as the forward portions of the blades 252. When the secondary and main pump wheels rotate as a unit the pumping action due to a change in cross section is lost if the inlet area to the secondary wheel is equal to the exit area of the pump wheel. This is desirable for the regime of low torque magnification.

In some applications where high efficiency should be maintained near the peak value over a wide range of torque magnification, it may be desirable to employ an auxiliary rotor 256 such as shown in Fig. 16 with the inlet radial depth smaller than the exit radial depth of the blades. That is rotor 256 and pump wheel 253 would replace 22 and 10 respectively in Fig. 1.

The reason for having the secondary rotor of smaller inlet area than the pump inlet area is that in the low torque regime (high turbine speed) the vector approaching the secondary rotor will be relatively steeper while in the high torque regime where the secondary rotor is free wheeling the approach vector to the main pump

wheel will be relatively flatter. Then the blades of the two wheels can be given more nearly the same inlet angles.

Although the hub structures shown are cylindrical it is to be understood that one side of the hub may be of smaller diameter than the other, making in effect a conical frustum. In fact a cylinder is a limiting case of a conical frustum, the case where the angle between the base and sides becomes a right angle. The cylindrical or conical surface may conveniently be called the peripheral surface.

The axial flow transmission is particularly adapted to stampings or sheet metal fabrication. The combination of axial flow with sheet metal stampings and the like represents a significant advance since it makes this economical type of fabrication suitable for fluid torque converters with the retention of simple forms for the sheet metal parts.

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 axial flow pumping means for raising the pressure of a fluid, a case, a wheel mounted in said case for rotation about an axis, said wheel including a hub, separate sheet metal upper and lower walls juxtaposed in spaced relation defining a plurality of hollow blades spaced peripherally about said wheel, said wheel being a pumping wheel with pumping passages between said blades arranged such that the angle between the forward portion of each blade and said axis is at least as great as that between the aft portion thereof and said axis, said upper and lower walls being secured together along the nose portion of each said blade and along the trailing edge thereof, sheet metal means fixed to each said wall of a blade and extending inward to said hub and being fixed thereto at axially spaced localities, said blades and said hub in operation developing a substantial increase in static pressure in said fluid flowing between said blades, and a rim means having rim elements extending in the general axial direction integrally from leading to trailing edges of said blades and extending from blade to blade adjacent to the root ends thereof to sustain said increase in pressure, said rim means being fixed to said blades.

2. In combination in an axial flow pumping means for raising the pressure of a fluid, a case, a wheel mounted in said case for rotation about an axis, said wheel including a hub, separate sheet metal upper and lower walls juxtaposed in spaced relation defining a plurality of hollow blades spaced peripherally about said wheel, said wheel being a pumping wheel with pumping passages between said blades arranged such that the angle between the forward portion of each blade and said axis is at least as great as that between the aft portion thereof and said axis, said upper and lower walls being secured together along the nose portion of each said blade and along the trailing edge thereof, sheet metal means fixed to each said wall of a blade and extending inward to said hub and being fixed thereto at axially spaced localities, said blades and said hub being adapted for rotation developing a substantial increase in static pressure in said fluid flowing between said blades, and a rim means extending in the general axial direction from leading to trailing edges of said blades and from blade to blade adjacent to the root ends thereof to sustain said increase in pressure, said rim means being fixed to said blades, and sheet metal plates on axially opposite sides of said sheet metal means, means fixing the front and rear edges of said rim means to said hub and enclosing said sheet metal means in cooperation with said rim means.

3. In combination in an axial flow pumping means for raising the pressure of a fluid, a case, a hub mounted in said case for rotation about an axis, wall means defining a plurality of hollow axial flow blades including a continuous lower-wall means extending from the trailing

edge of each said blade around the leading edge thereof and forming a substantial portion of the upper surfaces of each said blades, said blades being carried on said hub in peripherally spaced relation thereabout and having their tips contoured to said case to fit closely thereto along substantially their entire chordwise length, said wheel being a pumping wheel with pumping passages between said blades arranged such that the angle between the forward portion of each blade and said axis is at least as great as that between the aft portion thereof and said axis, a plurality of axially spaced sheet metal plates fixed to said blades and extending inward to said hub and being fixed thereto at axially spaced localities, said blades and said hub being adapted for rotation developing a substantial variation in pressure in said fluid flowing between said blades, and a pressed sheet metal rim means extending in the general axial direction connectedly from leading to trailing edges of said blades and from blade to blade adjacent to the root ends thereof to sustain said variation in pressure, said rim means being secured to said blades, and sheet metal means fixing the front and rear edges of said rim means to said hub.

4. In combination in an axial flow pumping means for raising the pressure of a fluid, a case, a hub mounted in said case for rotation about an axis, wall means defining a plurality of hollow axial flow blades including a continuous lower wall means extending from the trailing edge of each said blade around the leading edge thereof and forming a substantial portion of the upper surfaces of each said blades, said blades being carried on said hub in peripherally spaced relation thereabout radially outward therefrom and having their tips contoured to said case to fit closely thereto along substantially their entire chordwise length, said wheel being a pumping wheel with pumping passages between said blades arranged such that the angle between the forward portion of each blade and said axis is at least as great as that between the aft portion thereof and said axis, sheet metal elements fixed to opposite walls of each said blade and extending inward to said hub and being fixed thereto at axially spaced localities, said blades and said hub being adapted for rotation developing a substantial variation in pressure in said fluid flowing between said blades, and a pressed sheet metal rim means extending in the general axial direction connectedly from leading to trailing edges of said blades and from blade to blade adjacent to the root ends thereof to sustain said variation in pressure in co-operation with said case, said rim means being secured to said blades, and sheet metal means extending radially inward from said rim means and being fixed to the front and rear edges of said rim means and to said hub.

5. In combination in an axial flow pump, a wheel for developing fluid static pressure between the leading and trailing edges of the blades thereof, and a case enclosing said wheel to sustain said fluid pressure, said wheel comprising a hub structure including a front wheel plate and a rear wheel plate both of sheet metal and spaced apart axially defining a hollow hub interior, a plurality of hollow sheet metal blades peripherally spaced about said structure, said wheel being a pumping wheel with pumping passages between said blades arranged such that the angle between the forward portion of each blade and said axis is at least as great as that between the aft portion thereof and said axis, each said blade having opening means in a surface thereof leading into the blade interior, said blades extending inward beyond the perimeters of said plates to said structure for support thereby, each said blade having an opening into the interior thereof adjacent to the root thereof and communicating with said interior of said hub structure, and a plurality of rim segments of stamped sheet metal positioned between said plates and extending connectedly from one said plate to the other, each said rim segment having radially inturned flanges fixed to said plates, each said segment substantially closing the space between adjacent said blades

and said plates adapting said wheel to sustain substantial variation in fluid pressure between the leading and trailing edges of said blades, said hub structure having an opening for the admission of fluid thereinto.

6. In combination in an axial flow pump, a wheel for developing fluid static pressure between the leading and trailing edges of the blades thereof, and a case enclosing said wheel to sustain said fluid pressure, said wheel comprising a hollow hub structure including a wheel plate therewithin, said hub structure defining an opening into its interior for the flow of fluid therethrough, a plurality of hollow sheet metal blades, said wheel being a pumping wheel with pumping passages between said blades arranged such that the angle between the forward portion of each blade and said axis is at least as great as that between the aft portion thereof and said axis, each said blade having surface means for the passage of fluid there-through the hollow interior of the blade, said surface means being distributed radially in a radially directed surface of each said blade, and a rim means fixed to the root ends of said blades, said rim means extending from one blade to another closing the space therebetween, connecting sheet metal elements fixed to each side of each said blade and extending radially inward and supported on said wheel plate, said elements being spaced apart to provide communication between each said blade interior and said opening in said hub structure, said rim means extending along said blades substantially from leading to trailing edges thereof adapting said wheel to sustain variations in pressure between the leading and trailing edges of said blades.

7. A light weight axial flow wheel for a pumping means for increasing the pressure of a fluid comprising a separately fabricated annular hub member for receiving a driving torque, a plurality of hollow blades carried in said wheel and spaced peripherally thereabout, said blades being formed of sheet metal construction comprising sheet metal walls extending chordwise integrally across a bend line defining the leading edge of the blade, said blades providing light weight thereof and limiting the centrifugal forces developed therein at high rates of rotation with accompanying flow of said fluid in a generally axial direction between said blades, said wheel being a pumping wheel with pumping passages between said blades arranged such that the angle between the forward portion of each blade and said axis is at least as great as that between the aft portion thereof and said axis, and sheet metal means fixed to said blades and extending inward to said hub member and being secured thereto by a fused metal joint in shear to sustain said limited forces, said sheet metal means including a separately fabricated rim means of sheet metal construction and axially spaced sheet metal disks secured to said rim means and to said hub member at axially spaced localities embracing a portion of said member therebetween, said rim means extending between and closely conforming with the walls of said blades between the leading and trailing edges thereof to sustain a substantial difference in static pressure in said fluid flowing between said blades, said rim means having chordwise extending flanges directed radially inward adjacent to the sides of said blades and front and rear flanges extending peripherally and directed radially inward lapping the sides of said disks and being fixed thereto.

8. A light weight axial flow wheel for a pumping means for increasing the pressure of a fluid comprising a separately fabricated annular hub member for receiving a driving torque, a plurality of hollow blades carried in said wheel and spaced peripherally thereabout, said blades being formed of sheet metal construction comprising sheet metal walls extending chordwise integrally across a bend line defining the leading edge of the blade, said wheel being a pumping wheel with pumping passages between said blades arranged such that the angle between the forward portion of each blade and said axis is at

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least as great as that between the aft portion thereof and said axis, said blades providing light weight thereof and limiting the centrifugal forces developed therein at high rates of rotation with accompanying flow of said fluid in a generally axial direction between said blades, and sheet metal means fixed to said blades at the root ends thereof and extending inward to said hub member and being secured thereto to sustain said limited forces, said sheet metal means including a separately fabricated rim means of sheet metal construction and axially spaced sheet metal disks secured to said rim means and to said hub member, said rim means extending between and closely conforming with the walls of said blades and extending connectedly between the leading and trailing edges thereof to sustain a substantial difference in static pressure in said fluid flowing between said blades, said rim means comprising a plurality of rim segments each positioned between adjacent said blades with a radially directed flange adjacent to a side surface of a said blade and front and rear flanges each adjacent to a said disk and being fixed thereto by fused metal for supporting said rim means against centrifugal force.

9. A light weight axial flow wheel for a pumping means for increasing the pressure of a fluid comprising a separately fabricated annular hub member for receiving a driving torque, a plurality of hollow blades carried in said wheel and spaced peripherally thereabout, said wheel being a pumping wheel with pumping passages between said blades arranged such that the angle between the forward portion of each blade and said axis is at least as great as that between the aft portion thereof and said axis, said blades being formed of sheet metal construction comprising sheet metal walls extending chordwise integrally across a bend line defining the leading edge of the blade, said blades providing light weight thereof and limiting the centrifugal forces developed therein at high rates of rotation with accompanying flow of said fluid in a generally axial direction between said blades, and sheet metal means fixed to said blades at the root ends thereof and extending inward to said hub member and being secured thereto to sustain said limited forces, said sheet metal means including a separately fabricated rim means of sheet metal construction and axially spaced sheet metal disks secured to said rim means and to said hub member, said rim means extending between and closely conforming with the walls of said blades between the leading and trailing edges thereof to sustain a substantial difference in static pressure in said fluid flowing between said blades, said rim means comprising a plurality of rim segments each positioned between adjacent said blades with a radially directed flange adjacent to a side surface of a said blade and front and rear flanges each adjacent to a said disk and being fixed thereto by fused metal, said flanges being fixed to said blades by solder.

10. A light weight axial flow wheel for a pumping means for increasing the pressure of a fluid comprising a separately fabricated annular hub member for receiving a driving torque, a plurality of hollow blades carried in said wheel and spaced peripherally thereabout radially outward from said hub member, said wheel being a pumping wheel with pumping passages between said blades arranged such that the angle between the forward portion of each blade and said axis is at least as great as that between the aft portion thereof and said axis, said blades being formed of sheet metal construction comprising sheet metal walls extending chordwise integrally across a bend line defining the leading edge of the blade, said blades providing light weight thereof and limiting the centrifugal forces developed therein at high rates of rotation with accompanying flow of said fluid in a generally axial direction between said blades, and sheet metal means fixed to said blades at the inner ends thereof and extending inward to said hub member and being secured thereto to sustain said limited forces, said sheet metal means including a separately fabricated rim means

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of sheet metal construction and axially spaced sheet metal disks secured to said rim means and extending radially inward to said hub member, said rim means extending between and closely conforming with the walls of said blades between the leading and trailing edges thereof to sustain a substantial difference in static pressure in said fluid flowing between said blades, said sheet metal disks having straight line elements extending from a locality adjacent to said rim means to a locality adjacent to said hub member providing for said disks to sustain said blades in tension, said rim means having chordwise extending flanges directed radially inward adjacent to the sides of said blades and front and rear flanges extending peripherally and directed radially inward lapping the side surfaces of said disks and being fixed thereto.

11. A light weight axial flow pumping wheel for a pumping means for increasing the pressure of a fluid comprising a separately fabricated hub member for receiving a driving torque, a shaft secured to said hub member for support thereof for rotation about an axis, a plurality of blades carried in said wheel and spaced peripherally thereabout, said blades being fabricated separately from said hub member, said blades being of light weight and limiting the centrifugal forces developed therein at high rates of rotation with accompanying flow of said fluid in a generally axial direction between said blades with increased static pressure, sheet metal means secured to said hub member and positioned between the leading and trailing edges of said blades at the roots thereof and fixed substantially directly thereto along portions thereof between said leading and trailing edges and extending radially inward in a plane transverse to said axis and positioned between said leading and trailing edges of each blade at the root thereof for supporting said blades effectively against said limited centrifugal forces, and separately fabricated rim means of sheet metal construction connected to said sheet metal means and extending between said blades and continuously from leading to trailing edges of said blades while closely conforming with the streamline-shaped walls thereof from substantially the leading to the trailing edges thereof to sustain said increased static pressure in said fluid flowing between said blades.

12. A light weight axial flow wheel for a pumping means for increasing the pressure of a fluid comprising a separately fabricated hub member for receiving a driving torque, a shaft secured to said hub member for the rotation thereof, a plurality of blades fabricated separately from said hub member and carried in said wheel and spaced peripherally thereabout, said blades being of light weight construction limiting the centrifugal forces developed therein at high rates of rotation with accompanying flow of said fluid in a generally axial direction between said blades with increased static pressure, a disk separately fabricated from said hub member positioned between the leading and trailing edges of said blades at the roots thereof and secured thereto along portions thereof between said leading and trailing edges and extending inward to said hub member facing a radially extending side surface thereof positioned axially between said leading and trailing edges, said disk being bonded to said side surface by fused metal providing a joint in shear load to sustain said limited centrifugal forces, and a rim means of sheet metal construction connected to said disk and extending between and closely conforming with the walls of said blades and extending connectedly from leading to trailing edges thereof to sustain a substantial increase in said static pressure in said fluid flowing between said blades.

13. A light weight axial flow wheel for a pumping means for increasing the pressure of a fluid comprising a separately fabricated hub member for receiving a driving torque, a shaft secured to said hub member for the rotation thereof, a plurality of blades fabricated separately from said hub member and brazed in said wheel

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and spaced peripherally thereabout, said blades being of light weight construction limiting the centrifugal forces developed therein at high rates of rotation with accompanying flow of said fluid in a generally axial direction between said blades, disk means separately fabricated from said hub member positioned between the leading and trailing edges of said blades at the roots thereof and secured thereto along portions thereof between said leading and trailing edges and extending radially inward in a plane transverse to said axis and positioned between said leading and trailing edges of each blade at the root thereof for supporting said blades effectively against said limited forces, and a separately fabricated rim means of sheet metal construction connected to said disk means and extending between and closely conforming with the walls of said blades and extending connectedly from leading to trailing edges thereof to sustain a substantial difference in static pressure in said fluid flowing between said blades.

14. A light weight axial flow wheel for a pumping means for increasing the pressure of a fluid comprising a separately fabricated annular hub member for receiving a driving torque, a shaft secured to said member for the rotation thereof, a plurality of blades fabricated separately from said hub member and carried in said wheel and spaced peripherally thereabout, said blades being streamlined for efficient operation at high rates of rotation, said blades being of light weight construction limiting the centrifugal forces developed therein at said rates of rotation with accompanying flow of said fluid in a generally axial direction between said blades with increased static pressure, and sheet metal means secured to said hub member and to said blades along portions thereof between the leading and trailing edges and extending radially inward to sustain said limited forces, said sheet metal means including a rim means and a disk fabricated separately from said blades and hub member, said rim means extending between and closely conforming with the streamline sides of said blades from the leading to trailing edges thereof to sustain a substantial increase in said static pressure in said fluid flowing between said blades.

15. A light weight axial flow wheel for a pumping means for increasing the pressure of a fluid comprising a separately fabricated annular hub member for receiving a driving torque, a shaft secured to said member for the rotation thereof, a plurality of blades fabricated separately from said hub member and secured by fused metal in shear in said wheel and spaced peripherally thereabout, said blades being streamlined for efficient operation at high rates of rotation and being of light weight construction limiting the centrifugal forces developed therein at said rates of rotation with accompanying flow of said fluid in a generally axial direction between said blades with increased static pressure, and sheet metal means secured to said blades at the inner ends thereof and extending inward to said hub member faying a radially extending side surface thereof positioned axially between said leading and trailing edges, said disk being bonded to said side surface by fused metal providing a joint in shear load to sustain said limited centrifugal forces, said sheet metal means including separately fabricated rim means of sheet metal construction, and axially spaced disks fabricated separately from said blades and hub member, said rim means extending between and closely conforming with the sides of said blades from the leading to trailing edges thereof to sustain a substantial increase in said static pressure in said fluid flowing between said blades.

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16. A light weight axial flow wheel for pumping means for increasing the pressure of a fluid comprising a separately fabricated hub member for receiving a driving torque, a shaft secured to said hub member for support thereof for rotation about an axis, a plurality of blades carried in said wheel and spaced peripherally thereabout, said blades being fabricated separately from said hub member, said blades being of light weight and limiting the centrifugal forces developed therein at high rates of rotation with accompanying flow of said fluid in a generally axial direction between said blades, rim means of sheet metal construction providing light weight thereof and limiting the centrifugal forces developed therein, and sheet metal means secured to said hub member and positioned between the leading and trailing edges of said blades at the roots thereof and fixed substantially directly to said blades and said rim means and extending inward to said hub member and being bonded thereto by fused metal to sustain said limited forces, said rim means extending between and closely conforming with the walls of said blades and extending connectedly from leading to trailing edges of said blades to sustain said increased pressure in said fluid flowing between said blades.

17. In combination in an axial flow machine for pumping fluid, a case, a light weight bladed wheel mounted in said case for rotation about an axis for exchanging force with a fluid, said wheel comprising a separately fabricated hub member for receiving a driving torque for rotating said wheel, a shaft secured to said hub member for the rotation thereof, a plurality of light weight axial flow streamline blades carried in said wheel peripherally spaced thereabout, said blades each having convex upper contours and concave lower contours and being fabricated separately from said hub member limiting the centrifugal forces developed at the roots of said blades at high rates of rotation with accompanying flow of said fluid in a generally axial direction between said blades with increased static pressure, said wheel being a pumping wheel wherein said blades present said concave contours toward the direction of rotation, rim means of light weight sheet metal construction positioned adjacent the roots of said blades limiting the centrifugal forces developed therein, and axially spaced plates fabricated separately from said blades and said hub member bonded to said hub member by fused metal, said plates being secured to said blades and said rim means to sustain said limited forces, said rim means having radially directed legs faying said side plates and being bonded thereto, said rim means extending from front to rear of said wheel and from plate to plate closing the gap therebetween to sustain said increased pressure in said fluid flowing between said blades.

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