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SUPERSONIC COMPRESSOR WITH AXIALLY TRANSVERSE DISCHARGE

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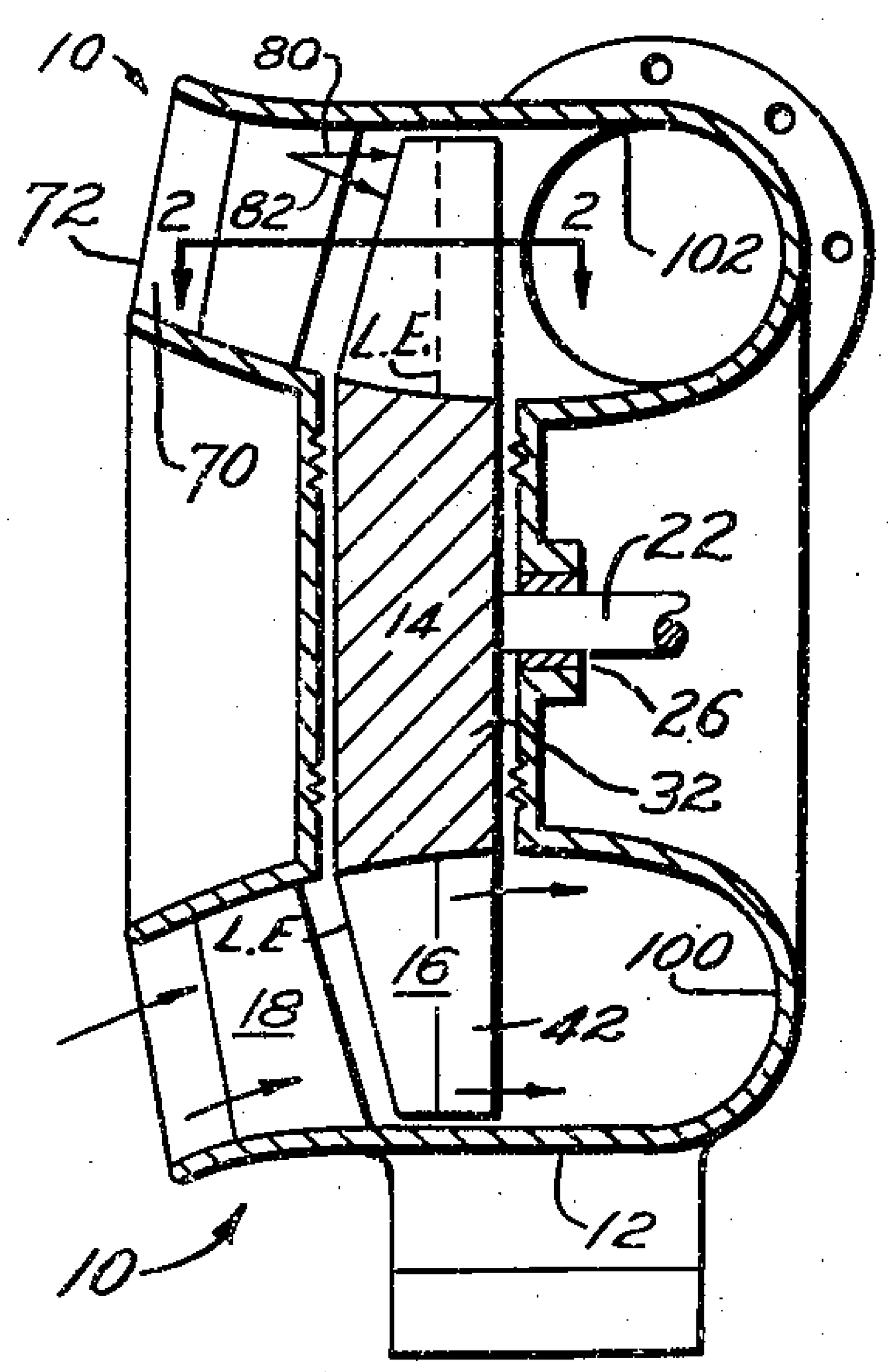

Fig. 1

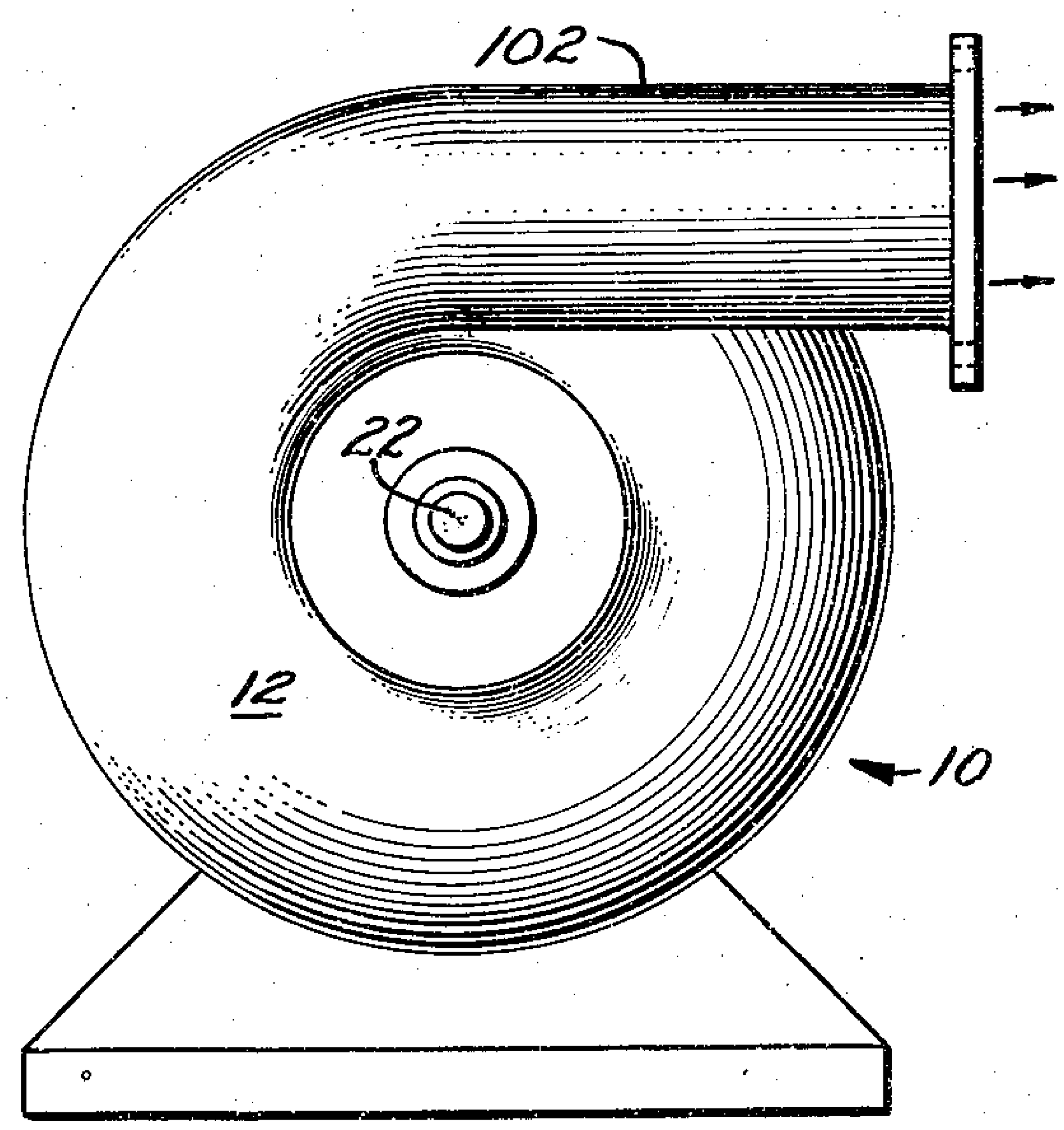

Fig. 3

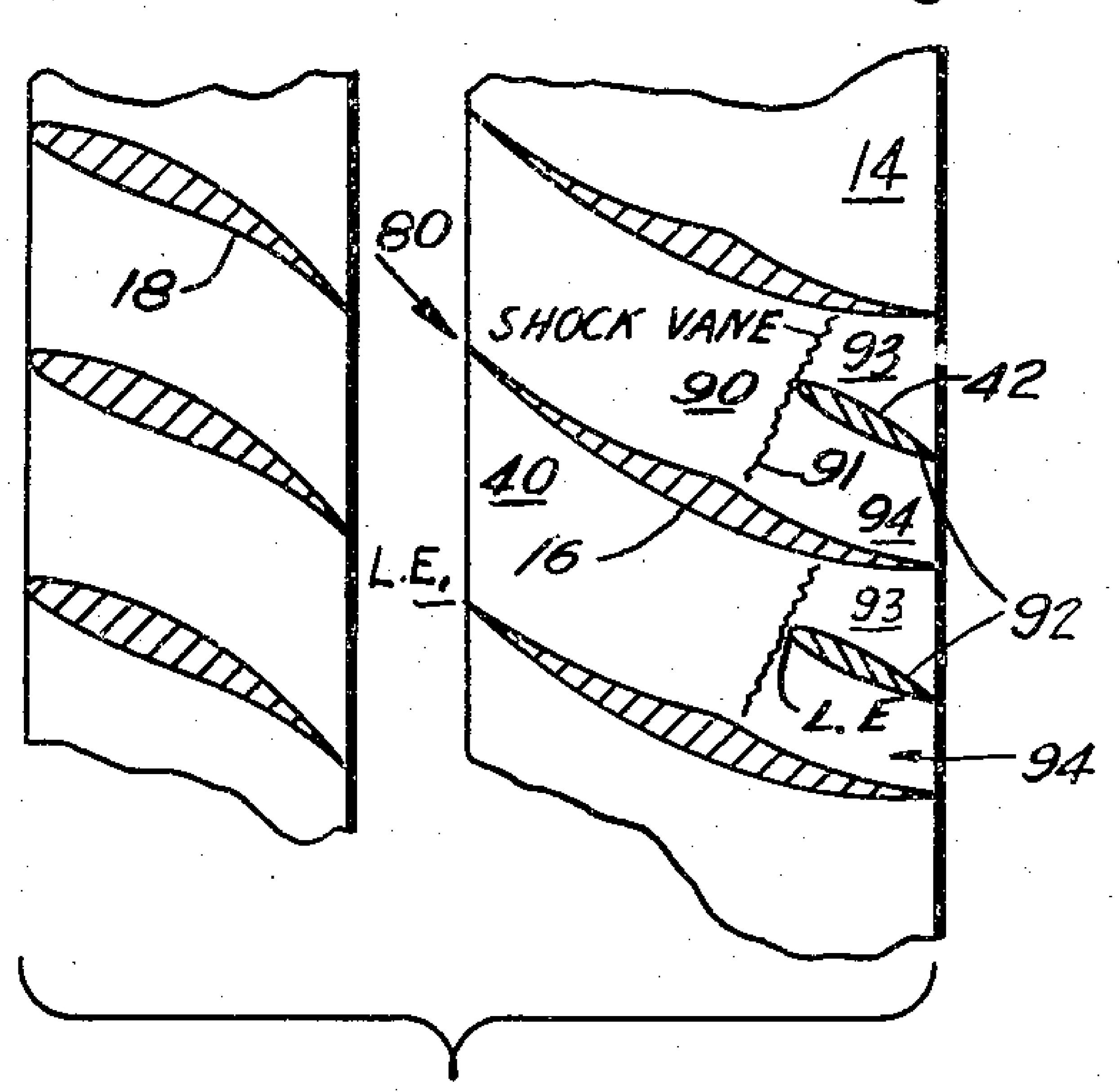

Fig. 2

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SUPERSONIC COMPRESSOR WITH AXIALLY TRANSVERSE DISCHARGE

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6 Claims. (Cl. 230—120)

This invention relates to compressors for elastic fluids.

An object of this invention is to provide a compressor whose rotating blades operate at supersonic velocity relative to the fluid or to the compressor case.

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

This application discloses a rotor similar in some respects to that in my application Serial No. 433,890 filed June 2, 1954, now Patent No. 2,839,239 entitled "Supersonic Axial Flow Compressors."

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

Fig. 1 is a fragmentary axial section through a compressor according to this invention;

Fig. 2 is a section of the blading on line 2—2 in Fig. 1; and

Fig. 3 is a rear axial view of the compressor of Fig. 1.

Referring now to the drawings, the compressor is indicated generally as **10** in Fig. 1. It comprises the case **12** and the rotor **14**. The rotor is mounted by shaft **22** in the bearings **26**. The inlet guide vanes are **18**.

The rotor **14** includes the hub **32** upon which are carried the rotor main blades **16** (Figs. 1 and 3) peripherally spaced thereabout with the rotor flow passages **40** between them extending from the front to the rear sides of the rotor. Between each pair of main blades there is an auxiliary element **42** whose function will be discussed subsequently.

The case and hub define an annular channel **70** having the annular inlet **72**. The rotor blades span this channel and preferably fit closely to the case at their tips along substantially their whole chord length.

When the rotors are rotated by means of one of the shafts, a flow of fluid, air for instance, is induced through the channel and at high rates of rotation the fluid velocity relative to the rotor blades becomes supersonic.

The rotor blades have their leading edges L.E. inclined rearward or downstream at their tips. Thus the leading edges are inclined to the relative flow vector **80** as shown in Fig. 1. This line passes through the leading edge. The magnitude of this vector **80** and the inclination of the leading edge are such that the normal component **82** is less than the speed of sound in the local fluid, that is fluid just ahead of the leading edge.

Since the component **82** is subsonic the flow will enter the rotor passages **40** without the formation of shock waves but will be supersonic in the passages.

The rotor passages preferably decrease in cross sectional area rearward therealong up to a throat **90**. The auxiliary element **42** in each passage has its leading edge preferably adjacent to or somewhat downstream from the throat. The leading edge L.E. of the auxiliary element is preferably less inclined or normal to the flow so as to precipitate a shock wave **91** which will stand in a position a short distance ahead of the edge. Aft of the shock wave the fluid velocity will be subsonic.

The auxiliary elements **42** define auxiliary flow passages **92** between them, each increasing in cross sectional area rearward therealong with each exit thereof greater in cross sectional area than each inlet of passages **40**. The main blades preferably extend rearward substantially parallel to the auxiliary elements **42** dividing the auxiliary passages into substantially equal portions **93** and **94** extending substantially in the general direction of the main blades.

Although it is preferred to precipitate the shock wave by having the leading edge of the element less inclined than the blade leading edge, the shock wave may also be precipitated by diverting the supersonic flow peripherally. This can be accomplished by making the leading edge of the auxiliary element relatively blunt or well curved or by giving the element a substantial thickness in the peripheral direction of the rotor.

The flow entering the rotor passages decreases in speed because of the rearward decreasing cross sectional areas. The flow remains supersonic but the velocity decreases toward the value of Mach number 1 at the throat. The minimum loss will occur if the shock wave occurs with the lowest Mach number. Accordingly the auxiliary element **42** preferably of blade shape has its leading edge near the throat. It will precipitate and stabilize a shock wave near its leading edge.

The rotor blades preferably have relatively sharp leading edges as shown in Fig. 2 and preferably the inlet guide vanes direct the flow against the direction of rotation of the rotor.

The shock wave converts the high supersonic velocity of the relative flow through the rotor passages to static pressure. The fluid at high static pressure flows into the collector space **100** and out the discharge duct **102**.

The passages **40** increase in cross sectional area rearward (downstream) from the location of the leading edge of the auxiliary blades **42** to accommodate the same mass rate of flow of fluid which is moving more slowly just aft of the shock wave. The fluid velocity is preferably further reduced well aft of the shock wave by the increasing cross sectional areas of the passages. Then at the exit the fluid has a large peripheral velocity component adapting the fluid to flow out the duct **102**, that is in a direction transverse to the axis of rotation.

It is preferred to have no fluid turning stator vanes in the circular cross sections of the case immediately adjacent the downstream side of the rotor. The flow leaves the rotor with chiefly a peripheral component of velocity and so is being directed chiefly transversely of the axis toward the exit duct without the aid of vanes.

It will now be clear that I have provided a novel compressor capable of high pressure ratios with high efficiency.

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 compressor for an elastic fluid, a case, an axial flow rotor mounted for rotation in said case comprising a hub and a plurality of peripherally spaced main blades carried thereon, said blades and said hub and said case in cooperation defining rotor flow passages for conduction of said fluid therein at supersonic velocity relative to said rotor, each said passage having a front portion of decreasing cross sectional area rearward therealong succeeded by a portion of rearward increasing cross sectional area defining a throat of each said passage between the front and rear sides of said rotor for reducing said supersonic velocity to a lower value thereof at said throat, each said blade having its leading edge substantially inclined relative to a line through said edge normal to the direction of said flow adjacent to said edge providing relative velocity components of said fluid normal to said edge of subsonic

values relative thereto, an auxiliary element in each said passage extending radially thereacross over substantially the whole radial extent thereof and subject to said supersonic relative fluid velocity therein with the leading edge of said element positioned adjacent to said throat and directed substantially more normal to said flow in said passage than the leading edges of said blades for precipitating a shock wave at the leading edge of each said element during operation of said compressor, and a shaft secured to said hub for rotating said rotor in said case at a blade tip speed relative to adjacent said fluid greater than the velocity of sound in said fluid upstream adjacent said blades during operation of said compressor, said case having circular cross sections thereof downstream adjacent said rotor and free of fluid turning stator vanes for receiving fluid from said rotor across said sections with chiefly a peripheral component of velocity said case having a discharge duct directed transversely to said axis for directing fluid from said case transversely to said axis.

2. In combination in an axial flow compressor for an elastic fluid, a case, an axial flow rotor mounted for rotation in said case comprising a hub and a plurality of peripherally spaced main blades carried thereon, said blades and said hub and said case in cooperation defining rotor flow passages for conduction of said fluid therein at supersonic velocity relative to said rotor, each said passage having a front portion of decreasing cross sectional area rearward therealong succeeded by a portion of rearward increasing cross sectional area defining a throat of each said passage between the front and rear sides of said rotor for reducing said supersonic velocity to a lower value thereof at said throat, each said blade blade having its leading edge substantially inclined relative to a line through said edge normal to the direction of said flow adjacent to said edge providing relative velocity components of said flow normal to said edge of subsonic values relative thereto, an auxiliary element in each said passage extending radially thereacross over substantially the whole radial extent thereof and subject to said supersonic relative fluid velocity therein with the leading edge of said element positioned downstream from said throat and directed substantially more normal to said flow in said passage than the leading edges of said main blades precipitating a shock wave at the leading edge of each said element during operation of said compressor, and a shaft secured to said hub for rotating said rotor in said case each at a blade tip speed for each said blade relative to adjacent said fluid greater than the velocity of sound in said fluid upstream adjacent said blades during operation of said compressor, said case having circular cross sections thereof downstream adjacent said rotor free of fluid turning stator vanes for receiving fluid across said sections from said rotor with chiefly a peripheral component of velocity, said case having a discharge duct directed transversely to said axis for directing fluid from said case transversely to said axis.

3. In combination in an axial flow compressor for an elastic fluid, a case, an axial flow rotor mounted for rotation in said case comprising a hub and a plurality of peripherally spaced main blades carried thereon, said blades and said hub and said case in cooperation defining rotor flow passages for conduction of said fluid therein at supersonic velocity relative to said rotor, each said passage having a front portion of decreasing cross sectional area rearward therealong succeeded by a portion of rearward increasing cross sectional area defining a throat of each said passage between the front and rear sides of said rotor for reducing said supersonic velocity to a lower value thereof at said throat, each said blade blade having its leading edge substantially inclined rearward providing relative velocity components of said fluid normal to said edge of subsonic values relative thereto, an auxiliary element in each said passage extending radially thereacross over substantially the whole radial extent thereof and subject to said supersonic relative velocity therein with the leading edge of said element adjacent to said throat, the forward portion of said auxiliary element being sufficiently blunt to precipitate a shock wave to reduce said supersonic velocity, and a shaft secured to said hub for rotating said rotor in said case at blade tip speeds relative to adjacent said fluid greater than the velocity of sound in said fluid upstream adjacent said blades during operation of said compressor, said case having circular cross sections thereof donwstream adjacent said rotor free of fluid turning stator vanes for receiving fluid across said sections from said rotor with chiefly a peripheral component of velocity, said case having a discharge duct directed transversely to said axis for directing fluid from said case transversely to said axis, said auxiliary elements also defining flow passages therebetween bounded by said hub and case and increasing in cross sectional areas rearward therealong.

4. In combination in an axial flow compressor for an elastic fluid, a case, an axial flow rotor mounted for rotation in said case comprising a hub and a plurality of peripherally spaced main blades carried thereon, said blades and said hub and said case in cooperation defining rotor flow passages for conduction of said fluid therein at supersonic velocity relative to said rotor, each said passage having a front portion of decreasing cross sectional area rearward therealong succeeded by a portion of rearward increasing cross sectional area defining a throat of each said passage between the front and rear sides of said rotor reducing said supersonic velocity to a lower value thereof at said throat, each said blade having its leading edge substantially inclined rearward providing relative velocity components of said fluid normal to said edge of subsonic values relative thereto, an auxiliary element in each said passage extending radially thereacross over substantially the whole radial extent thereof and subject to said supersonic relative velocity therein with the leading edge of said element downstream from said throat, said auxiliary element having a blade shape of sufficient peripheral thickness to precipitate a shock wave to reduce said supersonic velocity, and a shaft secured to said hub for rotating said rotor in said case at blade tip speeds relative to adjacent said fluid greater than the velocity of sound in said fluid upstream adjacent said blades during operation of said compressor, said case having circular cross sections thereof downstream adjacent said rotor free of fluid turning stator vanes for receiving fluid across said section from said rotor with chiefly a peripheral component of velocity, said case having a discharge duct directed transversely to said axis for directing fluid from said case transversely to said axis, said auxiliary elements also defining flow passages therebetween bounded by said hub and case and increasing in cross sectional areas rearward therealong.

5. In combination in an axial flow compressor for an elastic fluid, a case, an axial flow rotor mounted for rotation in said case comprising a hub and a plurality of peripherally spaced main blades carried thereon, said blades and said hub and said case in cooperation defining rotor flow passages for conduction of said fluid therein at supersonic velocity relative to said rotor, each said passage having a front portion of decreasing cross sectional area rearward therealong succeeded by a portion of rearward increasing cross sectional area defining a throat of each said passage between the front and rear sides of said rotor reducing said supersonic velocity to a lower value thereof at said throat, each said blade having its leading edge substantially inclined providing relative velocity components of said fluid normal to said edge of subsonic values relative thereto, an auxiliary element in each said passage extending radially thereacross over substantially the whole radial extent thereof and subject to said supersonic relative velocity therein, said elements each having its leading edge positioned adjacent said throat and having sufficiently curved contours to precipitate shock waves within said passage adjacent to or downstream of said throat to convert said supersonic velocity to static pressure during operation of said compressor, and

a shaft secured to said hub for rotating said rotor in said case at blade tip speeds relative to adjacent said fluid greater than the velocity of sound in said fluid upstream adjacent said blades during operation of said compressor, said case having circular cross sections thereof downstream adjacent said rotor free of fluid turning stator vanes for receiving fluid across said sections from said rotor with chiefly a peripheral component of velocity, said case having a discharge duct directed transversely to said axis for directing fluid from said case transversely to said axis, said auxiliary elements also defining flow passages therebetween bounded by said hub and case and increasing in cross sectional areas rearward therealong.

6. In combination in an axial flow compressor for an elastic fluid, a case, an axial flow rotor mounted for rotation in said case comprising a hub and a plurality of periphally spaced main blades carried thereon, said blades and said hub and said case in cooperation defining rotor flow passages for conduction of said fluid therein at supersonic velocity relative to said rotor, each said passage having a portion of rearward increasing cross sectional area, each said blade having its leading edge substantially inclined providing relative velocity components of said fluid normal to said edge of subsonic values relative thereto, an auxiliary element in each said passage extending radially thereacross over substantially the whole radial extent thereof and subject to said supersonic relative velocity therein, said elements each having its leading edge positioned downstream from the leading edges of said blades and having substantial peripheral thickness at the nose of said element to precipitate shock waves within said passages adjacent to or downstream of said throat to convert said

supersonic velocity to static pressure during operation of said compressor, and a shaft secured to said hub for rotating said rotor in said case at blade tip speeds relative to adjacent said fluid greater than the velocity of sound in said fluid upstream adjacent said blades during operation of said compressor, said case having circular cross sections thereof downstream adjacent said rotor free of fluid turning stator vanes for receiving fluid across said sections from said rotor with chiefly a peripheral component of velocity, said case having a discharge duct directed transversely to said axis for directing fluid from said case transversely to said axis, the leading edge of each said auxiliary element being positioned nearer the center of each said rotor passage than to said blades defining said passage.

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