Jan. 14, 1958 W. A. LOEB 2,819,837

COMPRESSOR

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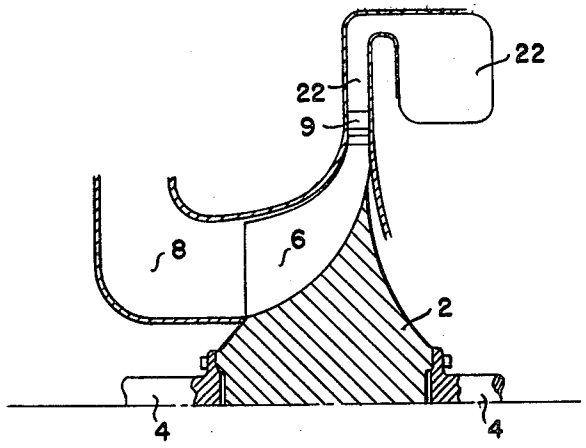


FIG. 1.

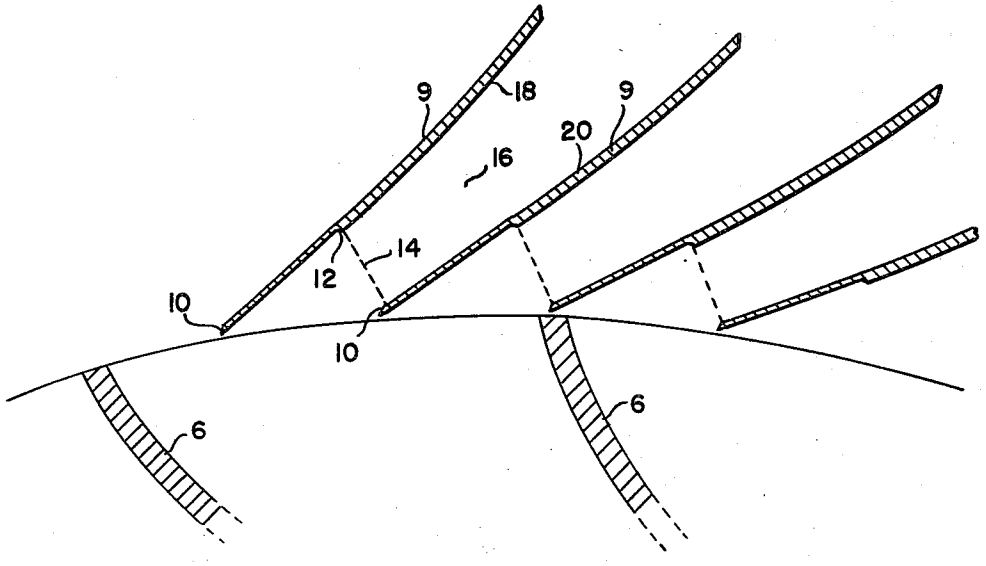


FIG. 2.

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COMPRESSOR

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2 Claims. (Cl. 230—127)

This invention relates to centrifugal or mixed-flow compressors and has particular reference to such type of compressor as involves superacoustic velocities of flow in certain parts thereof.

In the design of centrifugal and mixed-flow compressors it has been the general practice to avoid the use of velocities in the excess of the acoustic velocity, either locally or in the main stream, in order to avoid the flow losses generally attributed to the pressure shocks which may occur in this type of flow.

In accordance with the present invention, superacoustic velocities are purposely introduced in order to give rise to pressure shocks of proper type to gain various advantages previously unobtained.

First, there are secured characteristics of performance which are markedly different from those existing in the case of centrifugal or mixed-flow compressors operating throughout at sub-acoustic velocities of flow. In accordance with the invention the flow rate is essentially fixed by the rotational speed of the rotor, a characteristic heretofore attainable only in positive displacement types of compressors or in axial flow compressors.

Secondly, in accordance with the invention there are attained higher pressure ratios perstage at acceptable efficiencies than are possible in conventional centrifugal or mixed-flow compressors. In accordance with the invention the complete compressor may be either of the single or multiple stage type with the result that any desired pressure ratio may be obtained with fewer stages than are required by the conventional centrifugal or mixed-flow compressors giving a like overall pressure ratio. The result is that a compressor in accordance with the invention may be much lighter, smaller and simpler than a conventional compressor of like capacity.

Third, by the use of pressure shocks in accordance with the invention a large rise in pressure may be produced over a very short passage length. The passage length, therefore, may be appreciably shortened and the entire compressor is accordingly lightened, simplified, and made smaller.

The attainment of these desirable results in accordance with the invention will become apparent from the following description read in conjunction with the accompanying drawing, in which:

Figure 1 is a diagrammatic axial cross-section showing a single stage of a centrifugal compressor provided in accordance with the invention; and

Figure 2 is a fragmentary radial section showing the region about the periphery of the compressor rotor and the diffuser vanes.

The compressor rotor is indicated at 2 and in the present instance the compressor is illustrated as of the centrifugal type in which the flow leaves the rotor with radial and peripheral components but without a substantial axial component. It will be appreciated, however, that the compressor may equally well be of the mixed-flow type in which the flow from the rotor has a substantial axial

component as well as radial and peripheral components. The rotor 2 is mounted on shafting indicated at 4 and this shafting may be conventional, providing either for the drive of a single rotor in a single stage compressor or of a plurality of rotors in a multistage compressor. In the latter case it will be understood that the flow is redirected from the outlet of one stage to the inlet of the next succeeding stage.

Flow passages through the rotor are defined by blades 6 which need not be particularly described since they may take various forms in accordance with known design practices, being in general arranged in skew relationship to the axis of rotation at proper helix angles, considering the velocities of rotation, to impart to the elastic fluid leaving the rotor passages superacoustic velocity. The rotor passages receive the elastic fluid from a stationary passage 8 which in the case of a multiple stage compressor may receive compressed fluid from a previous stage.

The elastic fluid delivered from the rotor at superacoustic velocities is directed to a diffuser with which the invention is primarily concerned. Diffuser vanes 9, arranged around the periphery of the rotor, are provided with sharp leading edges indicated at 10 provided by bevels and arranged to provide smooth flow at the superacoustic velocities involved on the sides of the vanes which are directed radially inwardly. The last mentioned side of each vane is provided with an abrupt change in its surface in the form of a bevel indicated at 12 which is located with respect to the bevel 10 at the entrance edge of each vane at a position which, as indicated by the dotted line 14, is approximately directly opposite the bevel 10 from the standpoint of the direction of flow through the passages between the vanes. In other words, the line 14 indicates, substantially, the trace in the section of Figure 2 of a plane which is normal to the direction of flow, i. e., normal to the longitudinal axis of the passage 16 extending midway between adjacent surfaces of pairs of vanes 9. The result is that the bevels 10 and 12 provide a sharp and sudden decrease of cross-sectional area of the flow passage approximately at a single plane normal to the flow direction. Beyond the plane indicated at 14, each diffuser passage diverges in the same general fashion as in the case of a diffuser designed for subacoustic velocities, the bounding walls 18 and 20 both diverging and turning to some extent radially outwardly to decrease the peripheral component of flow. Beyond the trailing ends of the vanes 9 there may be provided further diffuser construction which in the instance illustrated involves the annular, radially extended passage 22 constituting a vaneless diffuser delivering the compressed fluid to the discharge volute 22 from which, in the case of a multistage compressor, the elastic fluid may be directed to the inlet of a subsequent stage. Instead of providing a vaneless diffuser as at 22, there may be provided a vaned diffuser involving vanes separate from vanes 9 or in the form of continuations of these vanes. In brief, beyond the planes indicated at 14, a diffuser construction is provided such as is characteristic of subacoustic compressors.

In the operation of the compressor, the flow leaving the rotor at superacoustic velocity meets the vanes and travels at superacoustic velocity in the case of each pair of vanes until there is reached the corresponding plane indicated at 14 where the abrupt slight decrease of cross-sectional area occurs by virtue of the bevels at 10 and 12. At these planes shock waves are produced giving rise to an abrupt increase of pressure and reduction of velocities to subacoustic values. Thereafter, in passage between the vanes and through the subsequent diffuser, such as

the vaneless diffuser 22, still further reduction of velocity occurs with concurrent increase of pressure.

It will be noted that the linear distance between the vane edge 10 and bevel 12 is relatively short and is desirably so to prevent the development of a substantial boundary layer ahead of the plane 14 at which the shock occurs.

While compression shock occurs as described, this shock is not attended with flow losses, but the result is merely an abrupt increase of pressure with reestablishment of relatively smooth flow at subacoustic velocities. The minimum flow area section corresponding to each plane 14 is accordingly the locus of a considerable pressure rise with the result that very substantial increase of pressure may be produced with a minimum length of flow path, the result being substantial decrease of radial dimension of the compressor as compared with a corresponding compressor operating at subacoustic flow velocities and having a comparable pressure ratio.

It will be evident that various details of the embodiment of the invention may be changed without departing from the scope thereof as defined in the following claims.

What is claimed is:

1. A compressor comprising a rotor having blades imparting to elastic fluid a superacoustic velocity of flow and a diffuser receiving flow from said blades at superacoustic velocity, said diffuser having relatively diverging vanes extending in a direction outwardly from said rotor defining passages receiving flow from the rotor passages at supersonic velocity, said vanes being non-radially extended and the leading edge of each vane being adjacent to a side of an adjacent vane, each vane being bevelled on the side of its leading edge facing an adjacent vane, and each vane being bevelled on its surface substantially directly opposite to the bevel of the leading edge of an adjacent vane providing an abrupt reduction in cross-section of the passage to give rise to shock waves in the superacoustic flow through the passage thereby producing abrupt rise in pressure therein, and means providing a diffuser beyond the location of said abrupt changes to provide rise of pressure at sub-acoustic velocities of flow.

2. A centrifugal compressor comprising a rotor for imparting to elastic fluid a superacoustic velocity of flow, and a diffuser having vanes diverging from each other extending in a direction outwardly from said rotor adjacent to the periphery thereof providing flow passages diverging in the direction extending generally outwardly from said rotor and receiving elastic fluid flow at superacoustic velocity from said rotor, said passages each having a longitudinal axis extending midway between adjacent surfaces of pairs of diffuser vanes, adjacent vanes of said diffuser having opposed abrupt shoulders projecting from the surfaces of the adjacent vanes on a plane substantially normal to the longitudinal axis of the passage extending between the adjacent vanes, only one of said shoulders being adjacent to the leading edge of one vane and said shoulders forming a restriction producing a shock wave giving rise to an abrupt increase of pressure and to a reduction of velocity of the elastic fluid from a superacoustic value to a subacoustic value.

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