

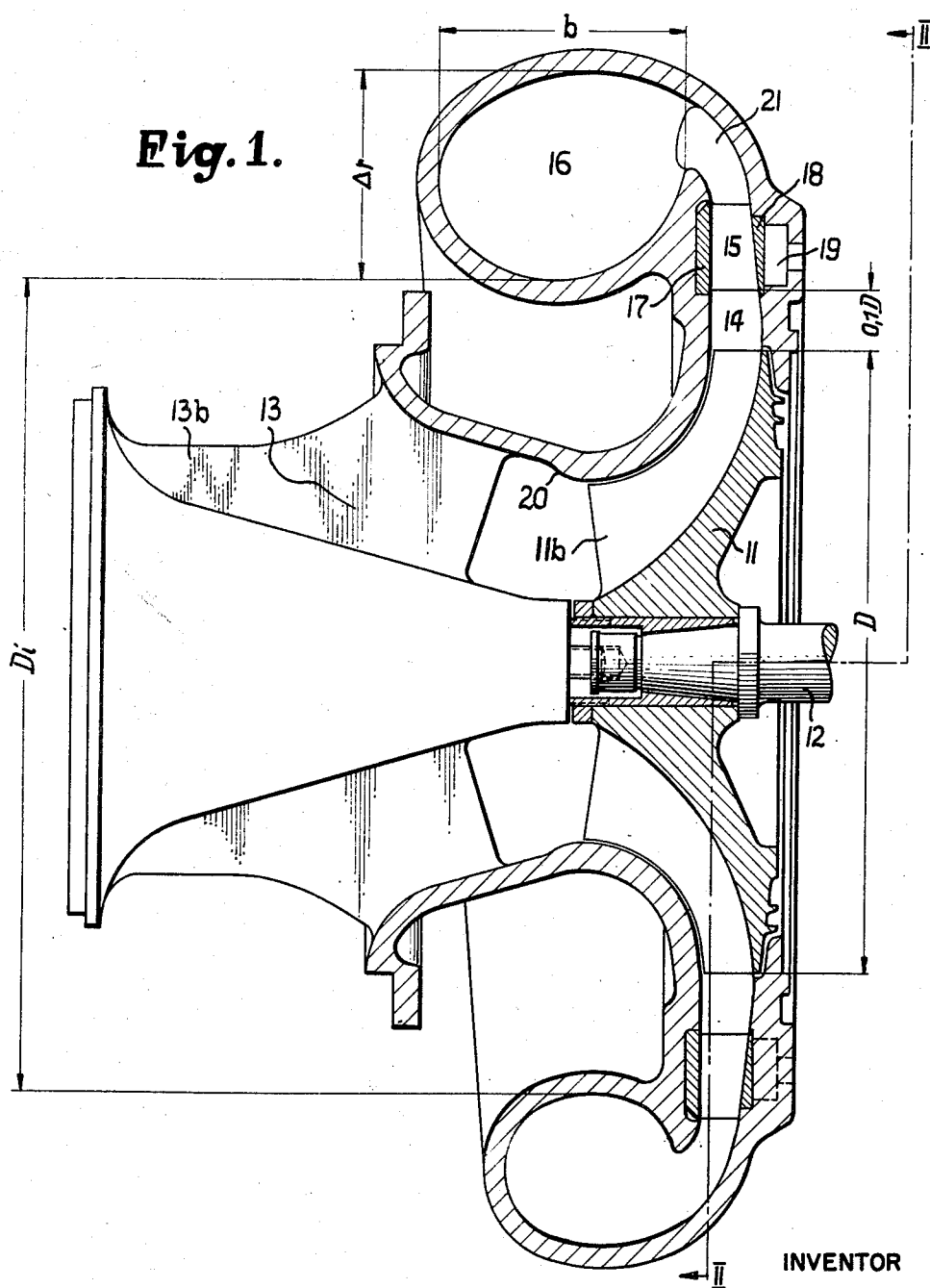
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A. GARVE
RADIAL-FLOW-COMPRESSOR

2,925,952

Filed June 25, 1954

2 Sheets-Sheet 1



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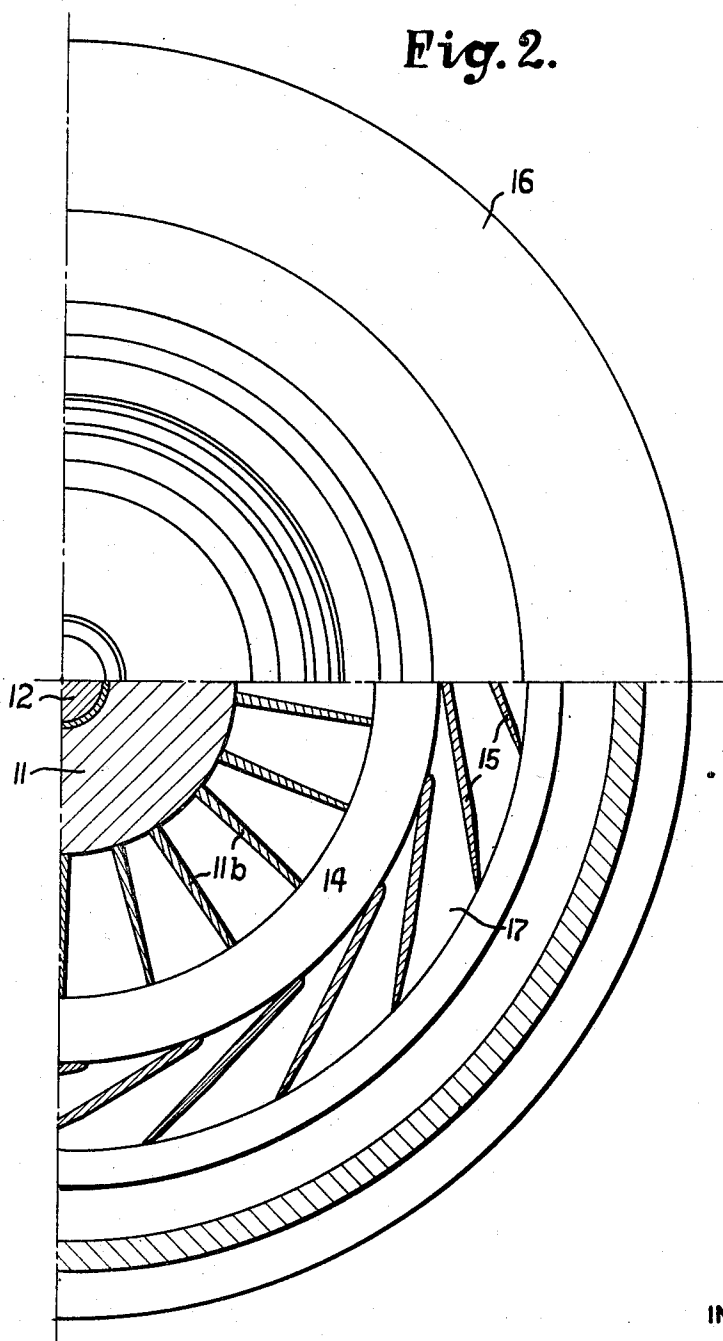
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Fig. 2.



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RADIAL-FLOW-COMPRESSOR

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This invention relates to radial-flow compressors such as gas and air compressors and the like, and more particularly to the construction, dimensioning, and configurations of inlet, discharge and collecting channels for radial flow compressors.

It has been discovered that the operating efficiencies of radial flow compressors can be substantially increased and the over-all size and complexity reduced by the proper configuration and dimensioning of the various inlet, discharge, and collecting channels through which the medium being compressed flows both before and after contact with the compressor rotor. Such compressors include particularly the radial flow type in which the air or other medium to be compressed flows into the compressor adjacent the center of the compressor rotor, is worked upon by the rotor blades, and is discharged around the periphery of the rotor and collected in a collecting channel under pressure to be led off to do work. Particularly with radial-flow compressors in applications such as airplane engines and the like, the efficiency of the compressor and the overall size thereof may be of great importance.

According to this invention, the advantages of substantially higher efficiencies and reduced size are obtained by providing an inlet channel of substantially diminishing cross sectional area to deliver the air, or gas or other medium to be compressed to the rotor adjacent the center thereof. Also a discharge channel of diminishing cross sectional area is provided at the discharge side of the rotor, and a spirally configured collecting channel of noncircular and increasing cross section is provided around the rotor to enhance the rectification and unification of the various directions of flow of the air or other medium being discharged by the rotor under pressure as well as the conversion of various velocity components of the flowing medium into pressure energy with a minimum of energy loss.

It is accordingly an object of the present invention to provide a radial flow compressor of the character described having inlet and discharge channels of gradually diminishing cross section along the line of flow there-through and a spirally disposed collecting channel of gradually increasing noncircular cross section arranged axially to one side of the radial plane of the discharge side of the rotor.

A further object of this invention is to provide in a radial flow compressor of the character described an inward jog or sudden substantial constriction of the inlet channel just before the rotor to effect increased acceleration of the working medium immediately before contacting the rotor blades and a diminishing of the effective cross sectional area of the channel into which the medium is discharged by the rotor blades.

Another object of this invention is to provide in a radial-flow compressor of the character described a discharge channel of a length which is kept consistent with constructional limits and increased efficiency yet is long enough to avoid the production of undue noise from the

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discharge thereinto of the working medium under pressure.

Still another object of this invention is to provide in a radial-flow compressor of the character described a spiral collecting channel with a noncircular cross section for increased efficiency in the conversion of velocity energy to pressure energy therein and means for offsetting the collecting channel from the radial plane of discharge by the rotor.

A still further object of the present invention is to provide in a radial-flow compressor of the character described a spiral collecting channel in which the axial and radial dimensions of the cross sections thereof are coordinated with the orientation of the channel with respect to the radial plane of discharge from the rotor and the diameter of the spiral in which the channel lies to provide for maximum efficiency with minimum space requirements and constructional complexity.

Other objects and advantages of this invention will be apparent from the following description, the attached drawing and the appended claims.

In the drawing,

Fig. 1 is an axial section through a compressor embodying this invention; and

Fig. 2 is a view partly in elevation and partly in section along the line II—II of Fig. 1.

In order better to understand this invention and the application of the teachings thereof to radial-flow compressor design, consideration of a number of factors concerning the flow of the air or other medium through the compressor may be helpful. Considering, for example, radial flow compressors in which the gas or other medium to be compressed is introduced in an axial direction adjacent the center of the rotor and thereafter passes radially outwardly among the rotary blades to be discharged at the periphery of the rotor, it will be apparent that the working medium undergoes a number of changes in direction and speed with concomitant variations in velocity, energy, and pressure. Thus, initially, the axially directed medium is contacted by the blades, given a rapid circumferential motion as well as being moved radially outwardly by the blades. Upon discharge at the periphery of the rotor under pressure, both velocities and directions of flow are again altered by the collecting conduits, etc.

The efficiency of the compressor, of course, depends considerably upon the extent to which these several alterations in direction of flow and velocity can be accomplished without loss of energy within the compressor. If it is attempted to control and utilize to a maximum extent the various flow characteristics of the working medium through the compressor merely by variations in the blade settings and design and/or the suitable dimensioning of the flow channels through the blades themselves, the best results are not obtained. Accordingly, the present invention concerns itself with the flow characteristics and energy relationships in the various flow channels before and after the rotor.

It has been discovered that enhanced results are obtained when the working medium at the inlet channel is given a strong acceleration just before contacting the rotor blades. This is particularly true in cases where constructional limitations on the inlet channel may produce variable conditions or may not be completely compensated for by known blade designs, and particularly with regard to the delaying or retarding effect of so-called diffuser blades which are used in pumps and compressors. Thus, at the entrance to the blades, there may take place not only a delay or retardation in axial direction of flow, but simultaneously a circumferential turbulence to produce separation of the working medium with attendant energy losses. Somewhat the same situ-

ation also obtains with the stator conduits on the discharge side of the rotor. Thus, the inlet channel of a compressor embodying this invention is produced with a gradually and constantly diminishing cross section for increased velocity and, in particular, is provided with a sudden and substantial jog or constriction immediately before the rotor to effect such preliminary acceleration of the medium therein.

Furthermore, the flow of the working medium upon discharge from the periphery of a radial flow compressor rotor may not be uniform. On the other hand, the energy conversion in the rotor may be more favorable and more efficient when the inlet flow to the rotor is uniform. By means of narrowing the cross section of the discharge channel between the rotor and the diffusion vanes, and the delay or retardation in the original direction which occurs thereat, differences not only in location but also in time between the velocities and pressures of individual stream lines are equalized.

Through the action of the whirling rotor, the medium receives a strong velocity component in a circumferential direction, as well as the axial and radial components imparted to it by the blades. Thus, upon discharge from the rotor, the medium flows outwardly along spiral paths in individual streams as created by the various rotor blades. This circumferential velocity component diminishes, however, with increasing distance from the axis of rotation and is, thus, inversely proportional to the radius. With diminishing velocity, accordingly, an energy conversion obtains providing an increase of pressure and a pressure gradient which increases radially outwardly as a result of the circumferential velocity component and at least insofar as the radial velocity component is not correspondingly increased by constrictions or lessening of the flow channel area.

Thus, it has been discovered that the effective cross sectional area of the discharge channel can be so substantially reduced that the flow therethrough is substantially rectilinear rather than spiral shaped notwithstanding the fact that the discharge channel is essentially a circular space surrounding the rotor. Although an energy conversion of velocity into pressure is desired as a net and end result of compressor operation, providing a discharge channel of sufficiently diminishing area to induce a rectilinear flow immediately before the diffusion vanes gives the advantage that the flow in each individual stream channel though the diffusion vanes is substantially as uniform as that in a straight or direct diffuser.

For effective use, however, the rapidly moving radially directed individual streams may be collected in a common conduit and led to the compressor outlet in the process of which the velocity energy should be converted into pressure. According to this invention a spirally configured collecting channel is provided for this purpose. A conversion of velocity into pressure can, of course, take place merely by reason of the torsion or twist induced into the streams of compressed medium by leading them into and through a spiral channel, in which case the velocity is diminished in an inverse proportion to the axis of rotation. Thus, a collecting channel laid in a spiral with as great a diameter as possible may provide an increased efficiency in the conversion of velocity into pressure, although it may also lead to an impracticably large over-all compressor size. On the other hand, reducing the diameter and tightening the spiral in which the collecting channel is disposed reduces compressor size but also decreases the efficiency of the energy conversion particularly in view of losses in drastically altering the direction of flow.

Also, if the collecting channel be given a substantially circular cross section so that the so-called hydraulic radius of the cross section is at a minimum to provide a minimum energy loss as with a straight conduit, maximum efficiency is not obtained. Thus, with curved or spiral conduits, there are, in addition to the normal fluid fric-

tion losses, losses originated by reason of the fact that a constant more or less turbulent mixture takes place between outer and inner stream lines, which mixture may give rise to substantial losses of flow energy. Such effect is proportionately less as the differences between the outer and inner radii of curvature and the center line radius of curvature are less. Hence, according to this invention, the cross section of the spiral channel is preferably noncircular with the axial dimension exceeding the radial dimension.

Also, according to this invention the spiral collecting channel has been found to give better results when positioned asymmetrically with respect to the direction of flow of the discharging medium from the rotor to the channel. Thus, with the cross sectional area of the collecting channel substantially bisected by the radial plane of flow of the medium from the rotor, the medium must be sharply deflected onto both the two side walls of the spiral channel upon entry therein if the cross section is to be kept within the desired radial limits of size. By contrast, a compressor embodying the present invention has the spiral collecting channel offset axially from the radial plane through which the medium flows upon discharge of the rotor so that the medium may be led by a curved annular conduit into one side of the collecting channel for uniform and efficient collection of the compressed medium all around the rotor and conversion of the high velocity energy therein to additional pressure energy.

Referring to the drawing, which illustrates a compressor embodying this invention and constructed in accordance with the foregoing, the rotor is shown as comprising a main rotor body 11 carrying thereon a plurality of blades 11b and mounted on a shaft 12 through which the rotor is driven in known manner. The air or gas or other working medium to be compressed is sucked in an approximately axial direction through the inlet channel 13. The walls of inlet channel 13 are supported by ribs 13b and constantly converge so that the effective cross section thereof constantly diminishes toward the rotor 11, thereby inducing an accelerating flow of the medium in channel 13. Just before the entrance to the blades 11b there is provided an inwardly protruding jog or shoulder 20 in the walls of channel 13 to effect a sudden substantial further constriction of the cross sectional area of the channel 13 and a consequent further rapid acceleration of the working medium immediately prior to contacting the blades 11b. Also, this sudden substantial constriction 20 effects an equalizing and straightening out of the individual flow stream-lines of the medium in channel 13 with a concomitantly more favorable flow pattern into and through the blades 11b of the rotor 11.

After the whirling blades 11b have compressed and set in motion the working medium, it is discharged at the periphery of the blades 11b into discharge channel 14 through which it moves rapidly in a spiral path by virtue of the above mentioned circumferential and radial velocity components imparted thereto by the blades 11b. The side walls of discharge channel 14 converge to provide a constantly diminishing cross section to effect further acceleration or velocity increase of the discharge medium prior to the introduction thereof through the stationary stator diffusion blading 15. Although the walls of the discharge channel 14 are shown as constantly converging, it may be desired to have them substantially parallel throughout most of the extent of channel 14 with a sudden substantial constriction immediately before the diffusion vanes 15 in the same manner as with the inwardly protruding jog or shoulder 20 in the inlet channel 13.

The diffusion vane stator ring comprises angularly disposed diverging diffusion vanes 15 mounted between rings 17 and 18 in the compressor housing by means of fastening screws through the openings 19 therein. The axial section of the diffusion vane ring tapers as does the discharge channel 14 and the angular arrangement and di-

vergence of the stator vanes 15 serve further for the conversion of velocity into pressure.

Thus, the flow of the working medium, after having been acted upon by the blades 11b on rotor 11, is equalized and objectionable separation from the side walls of the channels is prevented. The noise inherent in such radial flow compressors is, to a considerable extent, produced at this point in channel 14 where the discharged highly compressed and rapidly moving medium impinges upon the diffusion vanes 15. Accordingly, in order to maintain this noise within unobjectionable limits as well as to provide for the desired energy conversion in the discharge channel 14, the radial extent of channel 14 from the exit of the rotor blades 11b to the entrance to the diffusion blades 15 is preferably approximately $\frac{1}{10}$ of the outside diameter D of the rotor 11 and the blades 11b thereon.

As the working medium passes radially outwardly through diffusion vanes 15, a rectification of the direction of flow results in the individual stream lines. Upon exiting from the radially outer side of diffusion vanes 15, the radially directed streams of flow are led by the curved annular conduit 21 to the spiral collecting channel 16. Since the spiral channel 16 is axially displaced from the radial plane of the discharge side of blades 11b and diffusion ring 15 (i.e., the radial plane in which the various radially directed streams of compressing medium are flowing) a powerful energy conversion occurs upon the axial deflection of the streams of flow by the curved annular conduit 21. Preferably the effective axial width of conduit 21 from the exit of diffusion vanes 15 to the entrance into the spiral collecting channel 16 is approximately equal to the axial width of diffusion ring 15 at the radially outer exit thereof.

As noted above, the spiral collecting channel 16 is provided with a noncircular cross section in which the axial dimension *b* is greater than the radial dimension Δr . Satisfactory results according to this invention have occurred when the axial dimension *b* of channel 16 was approximately 20% to 60% greater than the radial dimension Δr . Since the cross sectional area of channel 16 increases substantially constantly along the full length thereof, it will be understood that the foregoing dimensional relationships apply to the various different axial and radial dimensions at different points along channel 16.

As noted above, channel 16 is disposed around the compressor essentially in the form of a spiral the inner diameter *D_i* of which is preferably at least as great as the radially inner diameter of diffusion vanes 15. In compressors which do not include diffusion vanes 15, the inner diameter of the spiral configuration of collecting channel 16 is preferably at least as great as the outer diameter of the rotor 11 with its blades 11b.

Thus the compressed medium flows in a spiral path along the radially outer housing walls of conduit 21 and collecting channel 16 and returns inwardly again after it has passed over a large part of the circumference of channel 16 about the axis of rotation to achieve an increased energy conversion at efficiencies hitherto regarded as unattainable while yet minimizing the over-all size of the compressor and its spiral collecting channel 16.

While the forms of apparatus herein described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise forms of apparatus, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. In a radial flow gas compressor structure having an open-ended bladed rotor adapted to receive a gas to be compressed adjacent the center of said rotor and to discharge said gas adjacent the periphery of said rotor, the combination which comprises an inlet channel in said structure having a peripheral wall for supplying said gas to said rotor, the cross-sectional area of said inlet channel

diminishing toward said rotor, an abrupt inward jog in said peripheral wall of said inlet channel adjacent the intake of said rotor forming a sudden substantial constriction in said inlet channel effecting an increased velocity in said gas immediately prior to the intake of said rotor, a plurality of diffusion vanes in said structure disposed in an annulus around the periphery of said rotor and radially spaced therefrom and defining an annular discharge channel between said rotor periphery and said diffusion vanes for conducting said gas discharged from the periphery of said rotor to said diffusion vanes, the axial dimension of said discharge channel and said diffusion vanes diminishing radially outward of said rotor and said annular discharge channel and vanes being correlated with the radial dimension thereof effecting substantial rectification of the flow lines of gas discharged from said rotor into substantially linear flow at said diffusion vanes, a spiral collecting channel in said structure for receiving said gas from said diffusion vanes, said spiral channel being displaced axially of said rotor and said diffusion vane annulus in said structure, and a curved annular conduit said structure for conducting said gas from said diffusion vanes to said spiral collecting channel.

2. A radial flow gas compressor according to claim 1 in which the radial dimension of said discharge channel from said rotor to said diffusion vane annulus is approximately one-tenth the diameter of said rotor and the inner diameter of said spiral configuration of said collecting channel is at least as great as the inner diameter of said diffusion vane annulus.

3. In a radial flow gas compressor structure having an open-ended bladed rotor adapted to receive a gas to be compressed adjacent the center of said rotor and to discharge said gas adjacent the periphery of said rotor, the combination which comprises an inlet in said structure having a peripheral wall for supplying said gas to said rotor, the cross-sectional area of said inlet channel diminishing toward said rotor, an abrupt inward jog in said peripheral wall of said inlet channel adjacent the intake of said rotor forming a sudden substantial constriction in said inlet channel effecting an increased velocity in said gas immediately prior to the intake of said rotor, a plurality of diffusion vanes in said structure disposed in an annulus around the periphery of said rotor and radially spaced therefrom and defining an annular discharge channel between said rotor periphery and said diffusion vanes for conducting said gas discharged at the periphery of said rotor to said diffusion vanes, said vanes being angularly disposed with respect to the axis of said rotor and diverging transaxially radially outwardly, the axial dimension of said discharge channel and said diffusion vanes diminishing radially outward of said rotor and said annular discharge channel and vanes being correlated with the radial dimension thereof effecting substantial rectification of the flow lines of gas discharged from said rotor into substantially linear flow at said diffusion vanes, a spiral collecting channel in said structure for receiving said gas from said diffusion vanes, said spiral channel being displaced axially of said rotor and said diffusion vane annulus in said structure and a curved annular conduit in said structure for conducting said gas from said diffusion vanes to said spiral collecting channel.

4. In a radial flow gas compressor structure having an open-ended bladed rotor adapted to receive a gas to be compressed adjacent the center of said rotor and to discharge said gas adjacent the periphery of said rotor, the combination which comprises an inlet channel in said structure having a peripheral wall for supplying said gas to said rotor, the cross-sectional area of said inlet channel diminishing toward said rotor, an abrupt inward jog in said peripheral wall of said inlet channel adjacent the intake of said rotor forming a sudden substantial constriction in said inlet channel effecting an increased velocity in said gas immediately prior to the intake of

said rotor, a plurality of diffusion vanes in said structure disposed in an annulus around the periphery of said rotor and radially spaced therefrom and defining an annular discharge channel between said rotor periphery and said diffusion vanes for conducting gas discharged at the periphery of said rotor to said diffusion vanes; the axial dimension of said discharge channel and said diffusion vanes diminishing radially outward of said rotor and being correlated with the radial dimension thereof effecting substantial rectification of the flow lines of gas discharged from said rotor into substantially linear flow at said diffusion vanes, a spiral collecting channel in said structure for receiving said gas from said diffusion vanes, said spiral channel being displaced axially of said rotor and said diffusion vane annulus in said structure, a curved annular conduit in said structure for conducting said gas from said diffusion vanes to said spiral collecting channel, the axial dimension of the cross-sectional area of said spiral collecting channel being greater than the radial dimension thereof, and the inner diameter of said spiral configuration of said collecting channel being at least as great as the inner diameter of said diffusion vane annulus.

5. A radial flow gas compressor according to claim 4 in which said spiral collecting channel is of constantly diminishing cross-section and the axial dimension of cross-sections of said collecting channel are approximately 20% to 60% greater than the radial dimension thereof.

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