

Aug. 14, 1945.

M. G. ROBINSON
CENTRIFUGAL COMPRESSOR

2,382,913

Filed April 12, 1943

2 Sheets-Sheet 1

Fig. 1.

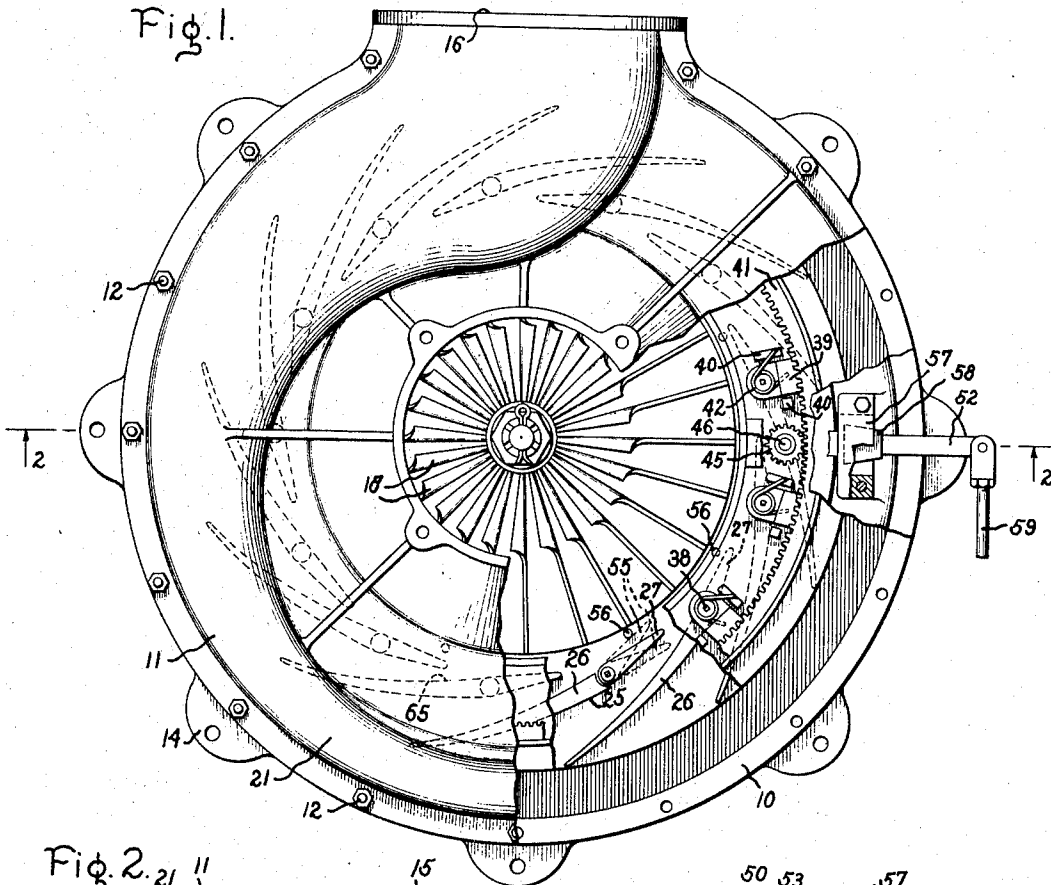


Fig. 2.

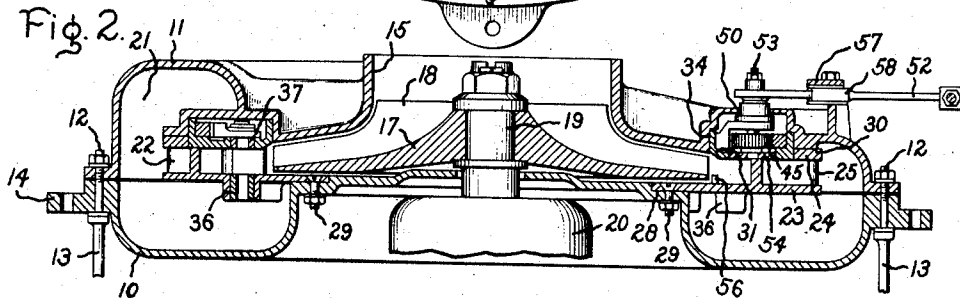
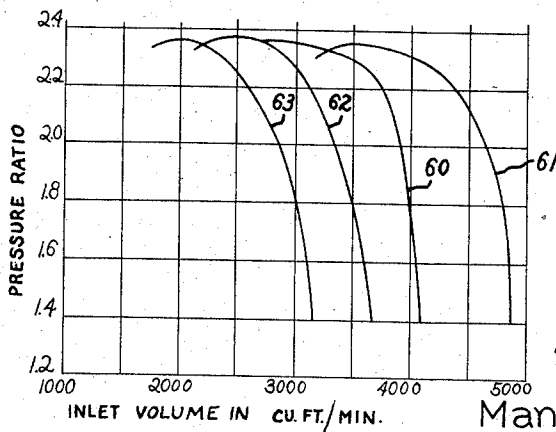


Fig. 5.



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Fig. 3.

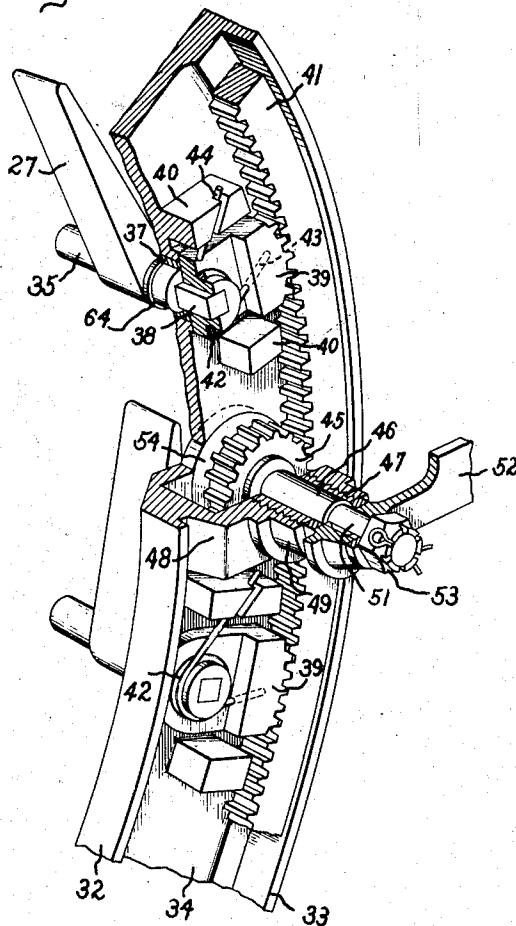
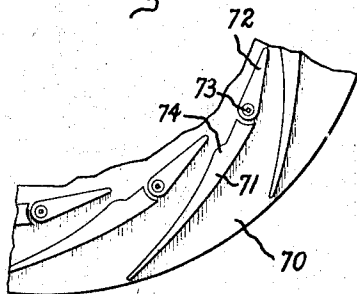


Fig. 4.



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UNITED STATES PATENT OFFICE

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CENTRIFUGAL COMPRESSOR

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6 Claims. (Cl. 230—114)

The present invention relates to centrifugal compressors having an impeller and a diffuser with a plurality of circumferentially spaced vanes surrounding the impeller and forming diffuser passages for converting the velocity energy of the impelled medium into pressure energy and for conducting such medium from the impeller passages into a scroll or discharge chamber. In many instances, such as when used on aircraft for supercharging internal combustion engines, it is desirable greatly to vary the flow of fluid through the compressor. In aircraft the supercharger is ordinarily dimensioned to furnish an amount of air required for full engine output at high altitude.

At low engine output, such as, during cruising of the airplane at low speed, the engine operates at reduced R. P. M. and hence reduced airflow. It may, however, for reasons of best fuel economy, require essentially constant B. M. E. P. (brake mean effective pressure) in the cylinders. To accomplish this, the supercharger speed must be maintained essentially constant in order to produce an essentially constant degree of compression, even though the volume flow drops considerably. The ordinary compressor with fixed diffuser vanes forming fixed passages becomes unstable at a certain minimum flow therethrough, especially when operated at high pressure ratio, that is, at a high ratio between the inlet and outlet pressures. In order to increase the range of operation of the compressor it has heretofore been suggested to provide a diffuser with adjustable vanes and to adjust the vanes upon certain changes in flow through the compressor.

There is an added advantage of the variable diffuser feature which is particularly important for applications where the compressor is called upon to operate over a wide range of conditions. For example, an airplane supercharger must run efficiently over a wide range of altitudes, this corresponding to a wide range of compression ratios and hence rotational speeds. Obviously, a fixed set of diffuser passages will be most efficient at some preselected conditions, and will be less and less efficient as we deviate from these. The use of the variable diffuser will compensate for these deviations and thus make possible more efficient operation over a wide range of conditions, thus increasing output and economy of the plant.

The object of my invention is to provide an improved construction and arrangement of centrifugal compressor with adjustable vanes which have a wide range of operation and may be oper-

ated throughout such range at an efficiency that compares favorably with that of corresponding compressors having fixed vanes. This is accomplished in accordance with my invention by the provision of a plurality of diffuser vanes with a major portion of each vane fixed and securely connected to a diffuser side wall and a relatively short inlet portion of each vane pivotally supported and arranged to be moved towards and away from the major fixed portion of an adjacent vane to vary the cross-section of the inlet portion of the diffuser passage formed with the adjacent vane.

For a better understanding of what I believe to be novel and my invention, attention is directed to the following description and the claims appended thereto in connection with the accompanying drawings.

In the drawings Fig. 1 illustrates a front view partly in section of a centrifugal compressor embodying my invention; Fig. 2 is a section along line 2—2 of Fig. 1; Fig. 3 is a perspective view of a part of Fig. 1; Fig. 4 is a modification of a diffuser according to my invention; and Fig. 5 illustrates several operating characteristics of the diffuser shown in Fig. 1.

The arrangement comprises a casing having two parts or halves 10 and 11 with flanges secured together by a plurality of bolts 12 which in the present example are held on studs 13 which may form a support for an exhaust gas operated turbine for driving the compressor. The flange of the casing half 10 has a plurality of spaced ears 14 for attaching the compressor to a support such as part of an aircraft. Inner portions of the two casing halves 10, 11 form an impeller chamber with an inlet opening 15 formed by the casing half 11. An outer portion of the casing halves forms an outlet 16 for discharging compressed air or like medium. A centrifugal impeller 17 with a plurality of blades 18 is disposed within the impeller chamber and secured to a shaft 19 projecting through an opening in the casing half 10 and held on a bearing 20. Outer portions of the casing halves form a scroll 21 which has a cross-section increasing towards the outlet 16.

During operation a medium to be compressed, such as air from the atmosphere, flows through the inlet 15 and is impelled by the impeller 17. The impelled medium is discharged from the impeller into the scroll 21 through a variable vane diffuser 22. This variable vane diffuser in the present example is substantially entirely disposed within the scroll and comprises two axially

spaced walls 23 and 24 and a plurality of circumferentially spaced diffuser vanes 25 forming passages between the walls 23, 24. Each vane 25 according to my invention has two portions, a major outer portion 26 which is stationary and in the present instance integrally united with the wall 23, and a minor inner or tip portion 27 which is adjustable. The side wall or ring 23 extends along the entire radial length of the vanes and has an inner portion secured to an annular recess 28 of the casing half 10 by means of a plurality of bolts 29. The other side wall or ring 21 comprises two ring members, an outer ring member 30 which extends only over radial short outer parts of the stationary wave portions 26 and is integrally united therewith, and another ring member 31 which extends over the remaining parts of the vanes and is detachably held on the casing. The other ring member 31, as best shown in Fig. 3, forms a channel, U-shaped in section, with cylindrical side walls 32, 33 and a bottom 34, disposed in an annular lateral recess or chamber formed by the casing half 11 and partly enclosed by the scroll thereof. When assembled the bottom 34 abuts against the edges of the stationary vane portions 26 and the cylindrical walls 32, 33 engage cylindrical surfaces formed by the casing half 11 and with their edges abut against the inner surface of the casing half 11, thus precluding axial movement of the ring or channel member 31.

The movable tip or inlet portions 27 of the diffuser vanes are supported on the ring member 31 and the diffuser side wall 23. To this end each tip portion is provided with a shaft 35 rotatably supported on bearing bushings 36 and 37 made of bronze or like suitable material and held in openings of the side wall 23 and the bottom 34 of the ring member 31. Each shaft 35 has an extension 38, square in section, and projecting into the channel formed by the ring member 31. The square shaft extensions 38 are secured to circumferentially spaced gear segments 39 located between pairs of spaced stop members 40 formed on the bottom 34 of the ring member 31. The gear segments 39 mesh with an internal ring gear 41 located within the channel formed by the ring member 31 and having outer walls forming clearances with the adjacent walls of the ring member and the casing so that the internal gear practically floats on the segments 39 and may be rotated by a small force. Backlash between the segments 39 and the internal ring gear 40 is reduced by a separate spring 42 for each segment which has a helical portion surrounding a hub of the segment and one end portion 43 connected to the segment and another end portion 44 held in a slot formed in one of the stops 40. Thus, when viewed in Fig. 3 the spring 42 biases the segment 39 in clockwise direction into engagement with the internal gear 41. The torsion springs besides reducing the backlash between the gears have another important effect in that they steady the movable vane portions 27 by providing damping forces and thus counteracting the tendency of the tip portions 27 to flutter during operation. The elimination of backlash between the internal gear 41 and the segments 39 and the square connection between the segments and the different vane portions 27 assures uniform positioning of the latter. The position of the variable vane portions may be varied by rotating the internal gear 41. The angle of rotation of the internal gear is limited by the pairs of stops 40 for the individual gear segments 39.

The mechanism for moving the internal gear comprises a gear 45 located within the channel of the ring member 31 between a pair of segments 39 and meshing with the internal gear 41. The gear 45 is secured to a shaft 46 which on one side projects through the casing half 11 and is supported by a bronze bearing 47 held on a bracket 48 formed by the ring member 31. The bracket 48 has a cylindrical portion 49 surrounding the bearing 47 and sealed to an opening 50 (Fig. 2) of the casing half 11. A reduced extension 51 of the shaft 46 is secured to an operating lever 52 by means including a nut 53. The shaft 47 on the other side of the gear 45 is supported in a bearing formed by a disk 54. This disk 54 is of slightly larger diameter than the gear 45 and held in an opening in the bottom 34 of the ring member 31. On one side the disk 54 bears against a shoulder formed on the shaft 46 and on the other side against a stationary vane portion 26.

During assembly the internal gear and the gear segments with the movable vane portions 27 are assembled on the ring member 31. The gear 45 with the disk 54 is inserted through the opening in the bottom 34 of the ring member 31. Upon completion of the assembly the ring member 31 is inserted into the annular channel formed by the casing half 11 and thereafter the operating lever 52 is attached to the shaft extension 51.

With this arrangement the movable vane portions 27 may be moved towards and away from the adjacent stationary vane portions. The inner and outer end positions of a movable vane portion have been indicated in dash-dotted lines 55 in Fig. 1. The end positions are determined by the pairs of fixed stops 40 which limit rotary movement of the gear segments 39. It is particularly important to limit the inner end positions of the movable vane portions in order to prevent them from coming into the path of the rotating impeller. To this end as an additional safety means I may provide a stop 56 adjacent each movable vane member to limit its inner end position. This is especially important in case the vane members 27 are shrunk or otherwise secured to separate shafts 35 because if the connection between the shaft 35 and the vane member 27 should become loose the vane member 27 is limited from movement towards the impeller by a stop 56 formed on the diffuser side wall 23. In the present example I have shown an additional means for limiting angular movement of the internal master or ring gear 41. This means is in the form of a bracket 57 bolted to the casing half 11 (Figs. 1 and 2) and limiting angular movement of the lever 52. The lever has an enlarged portion 58 which engages the bracket in the end positions of the lever 52. The outer end of the lever 52 is connected to a control rod 59 which latter may be actuated manually or by a governing mechanism, not shown.

During normal load output of the compressor the movable diffuser vanes are held in the position shown in full lines and dotted lines respectively in Fig. 1. In this position of the movable diffuser blade portions the compressor has a characteristic indicated by a curve 60 in Fig. 5. This curve shows the change of inlet volume in cubic feet per minute, that is, the rate of flow upon change in pressure ratio. Thus, with a ratio of 1.8 between the outlet and inlet pressures of the compressor the rate of flow through the compressor is about 4000 cubic feet per minute. This

rate of flow decreases with increasing pressure ratio and increases slightly with decreasing pressure ratio. Such decreasing and increasing pressure ratio in the case of an aircraft may be due to variation in altitude. If it is desired to increase the rate of flow at the same pressure ratio of 1.8 to a maximum, the movable vane portions are turned inward towards the impeller until they reach their inner end positions 55, as fixed by stops 56, in which they form diffuser passages of a maximum area with the adjacent stationary vane portions. In this position the compressor has a characteristic as shown by curve 61 and at a pressure ratio of 1.8 may furnish compressed air at a rate of about 4800 cubic feet per minute. With increasing pressure ratio the rate of flow will decrease again and the rate of flow decreases to about 3200 cubic feet per minute at a pressure ratio of 2.3. This is the minimum stable flow that can be obtained with the movable vane portions in their inner end positions 55. A further reduction in the rate of flow at stable compressor operation is obtained by moving the movable blade portions outward into different positions. In Fig. 5 the curve 62 illustrates the compressor characteristic in an outer position of the movable vane portions 27 and the curve 63 illustrates the compressor characteristic with the movable vane portions 27 in their outer end positions. This end position, as pointed out above, is determined by engagement between the segmental gears 29 with one of the stops 40. From Fig. 5 it can be seen that a minimum rate of flow through the compressor of about 1750 cubic feet per minute is obtained at a pressure ratio of about 2.32.

Thus, by the provision of movable blade portions the range of stable operation of the compressor may be considerably increased. A compressor of this kind may be operated at high efficiency because no cross leakage takes place across the stationary vane portions and the cross leakage across the movable vane portions is negligible because of their comparatively short length. In a preferred embodiment, as shown, the length of the movable portion of a vane may be of the order of one third of the total length of the vane. To keep the leakage across the movable vane portions at a minimum it is desirable carefully to machine the edges of the movable vane portions 27 and the adjacent surfaces of the ring member 31 and the side wall 23 which cooperate with the movable vane. However, small clearances should be maintained between the edges of the movable vane portions 27 and the adjacent surfaces of the diffuser side walls to reduce friction between them to a minimum. This may be satisfactorily accomplished by the provision of short shoulder portions 64 around the shaft 35 adjacent the movable vane portions. With such arrangement small areas only formed by the shoulder portions 64 on the vane 27 come into actual contact with the side walls. In the present example the shoulder portions 64 bear against end faces of the bushings 37 for supporting the shafts 35.

In the arrangement shown in Figs. 1 and 2 each stationary or fixed vane portion has a concave shaped surface 65 adjacent a movable vane portion. In certain instances, especially when the compressor often operates at a low rate of flow, a nozzle passage is thus formed which does not give the most desirable results. In such cases it is desirable to use a vane structure as

shown in Fig. 4 comprising a side wall 70 corresponding to the side wall 23 of Fig. 2 and a plurality of vanes each having a major outer stationary portion 71 secured to or integrally formed with the wall 70 and a minor short inlet portion 72 adjustably held by a pivot or shaft 73 on the wall 70. Each stationary vane portion 71 according to this modification has a thickened part or bulge 74 essentially convex shaped for cooperation with the movable portion 72 of an adjacent vane. The thickened portion 74 of the stationary vane portion 71 together with the adjustable portion of the adjacent vanes forms a more efficient nozzle shape when the adjustable vane portion is moved outward towards the thickened portion as compared with the nozzle shaped form by the corresponding parts in Fig. 1. Otherwise the construction of the compressor may be the same as described above in connection with Fig. 1.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. Centrifugal type compressor comprising a casing forming an impeller chamber and a discharge scroll, an impeller disposed in said chamber, and a diffuser for conducting medium impelled by the impeller into the discharge scroll comprising side walls and a plurality of circumferentially spaced vanes between the side walls, each vane having a major outer portion fixed to a side wall and a minor inner portion appreciably shorter than the major portion and pivotally supported on the side walls, the minor portion forming a close clearance with the respective major portion and having an outer surface shaped to form in all positions of the minor portion a smooth continuation of the outer surface of the major portion, the minor portion of the vane also cooperating with the fixed portion of the next adjacent vane to form a minor portion of the diffusing passage

2. Centrifugal type compressor comprising a casing forming an impeller chamber and an annular discharge chamber surrounding the impeller chamber, and a diffuser for conducting medium from the impeller chamber to the discharge chamber, said diffuser including a plurality of circumferentially spaced vanes each having a stationary portion and an adjustable portion, and means for uniformly moving the adjustable vane portions comprising a separate gear segment for each adjustable vane portion, a ring gear meshing with all the gear segments, means to reduce fluttering of the movable vane portions and for eliminating backlash between the gear segments and the internal gear, said gear segments and internal gear being sealed into the casing.

3. Centrifugal type compressor comprising a casing forming an impeller chamber and an annular discharge chamber surrounding the impeller chamber, and a diffuser for conducting compressed medium from the impeller chamber to the discharge chamber, said diffuser including a plurality of circumferentially spaced vanes each having a stationary portion and an adjustable portion, means for uniformly moving the adjustable vane portions comprising a gear segment for each adjustable vane portion, a ring gear meshing with all the gear segments, means for eliminating backlash of the gear segments and to reduce fluttering of the movable vane portions, and means for positioning the ring gear comprising a gearing meshing with the ring gear disposed within the casing and having a shaft

projecting through an opening of the casing and a lever for rotating said shaft.

4. Centrifugal type compressor comprising a casing forming an impeller chamber and a discharge scroll surrounding the impeller chamber, and a diffuser for conducting impelled medium from the impeller chamber to the discharge scroll comprising a plurality of circumferentially spaced vanes each having a stationary outer portion and an adjustable inner portion, and means for uniformly positioning the inner portions to form nozzle passages of different cross-sectional areas with the stationary portions of adjacent vanes comprising an annular channel structure forming a side wall for the diffuser and an annular chamber with the casing, an internal gear located in said annular chamber and a plurality of gear segments each secured to an adjacent vane portion and meshing with the internal gear, means formed in said annular channel to limit movement of the gear segments, and means connected to the gear segments to reduce fluttering of the adjustable vane portions.

5. A vane type diffuser for centrifugal compressors comprising a side wall, a plurality of circumferentially spaced vanes each having a major stationary portion with a thickened part integral with the side wall, and a minor adjustable inlet portion pivotally supported on the side wall and cooperatively associated with the thickened part of the stationary portion of an adjacent vane to form a minor portion of the diffusing passage.

6. Vane type diffuser for centrifugal compressors comprising a side wall, a plurality of circumferentially spaced curved vanes each being essentially convex on one side and concave on the other side and each vane having a major stationary part rigidly secured to the side wall with a thickened convex part on its concave side, and a minor adjustable inlet portion pivotally held on the side wall and in cooperative relation with the thickened part of an adjacent vane to form a minor portion of the diffusing passage.

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