Oct. 22, 1946. E. L. COE 2,409,836

CENTRIFUGAL TYPE COMPRESSOR

Filed April 21, 1944

Fig. 1.

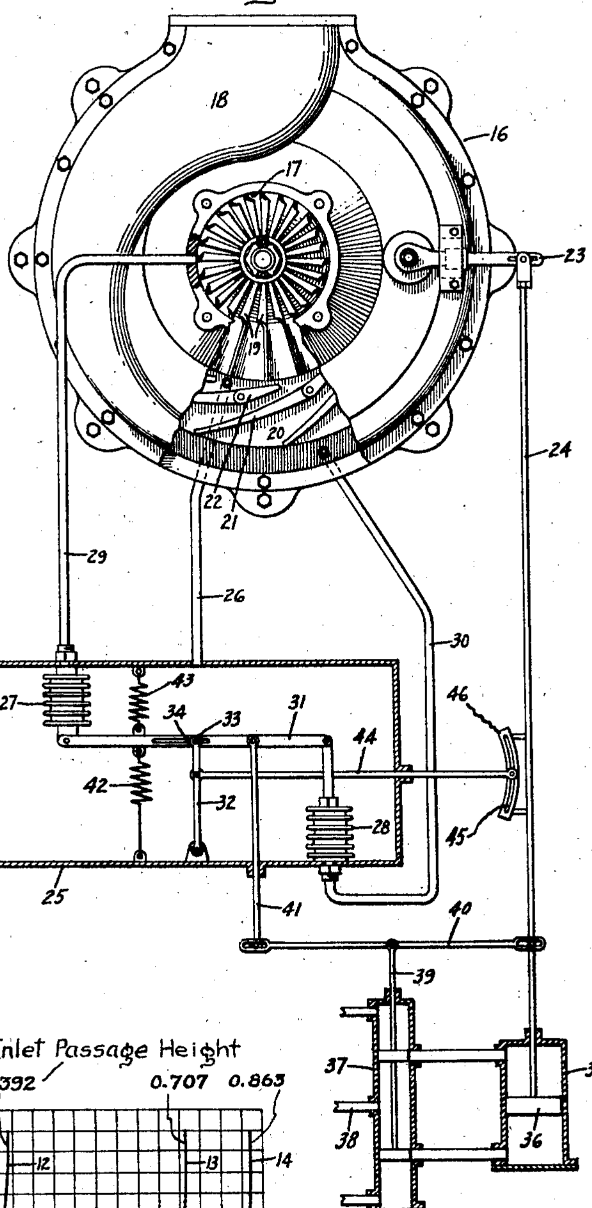
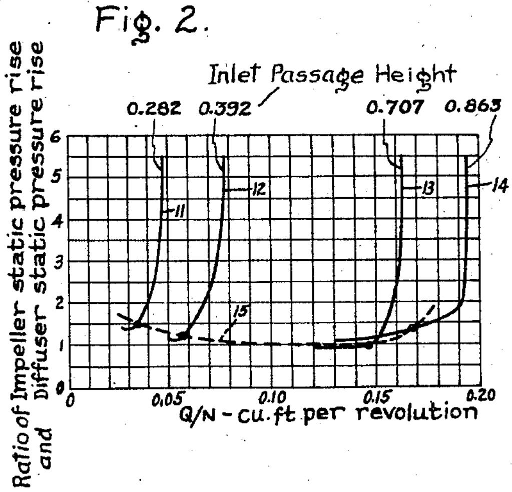


Fig. 2.



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CENTRIFUGAL TYPE COMPRESSOR

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Application April 21, 1944, Serial No. 532,047

6 Claims. (Cl. 230—114)

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The present invention relates to centrifugal type compressors with variable vane diffusers for supercharging aircraft and control mechanisms for the diffuser of the general type described in the copending application of J. S. Alford, Serial No. 532,107, filed on the same date and assigned to the same assignee as the present application.

The object of my invention is to provide an improved construction and arrangement of compressors with variable vane diffusers and control mechanisms for positioning said diffusers in response to changes of certain operating conditions, whereby best efficiency and economy are attained throughout the working range of the compressor.

For a consideration 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 drawing.

In the drawing, Fig. 1 illustrates an arrangement embodying my invention; and Fig. 2 illustrates certain compressor characteristics.

In the aforementioned application of J. S. Alford, a control mechanism for positioning variable vane diffusers is described whereby substantially constant ratio of pressure change or rise across the impeller and the diffuser is maintained within a wide range of operation of the compressor. I have found that best compressor performance and efficiency are attained if the ratio of pressure change across the impeller and the diffuser is maintained substantially constant within a certain range from the mean position of the diffuser vanes and if outside said range said ratio is gradually increased with increasing rate of flow per revolution at high load output and with decreasing rate of flow per revolution

$$\frac{Q}{N}$$

at low load output. To make this clearer, attention is directed to the diagram of Fig. 2 which shows four curves 11, 12, 13, and 14, each illustrating for a certain diffuser vane position the ratio of the impeller static pressure rise and the diffuser static pressure rise over

$$\frac{Q}{N}$$

representing cubic feet per revolution or quantity or rate of air flow through the compressor per revolution. The curve 11 shows the compressor performance for an inlet passage height of the different passages of .282 inch. The inlet passage height, sometimes called "throat opening",

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is the shortest distance between adjacent diffuser vanes. With a throat opening of .282 the compressor becomes unstable or starts to pulsate at

$$\frac{Q}{N}$$

below .03. With increasing

$$\frac{Q}{N}$$

the pressure ratio increases rapidly. The best efficiency of the compressor is attained at

$$\frac{Q}{N}$$

of .035 and a pressure ratio of 1.5 indicated by a small circle on curve 11. The curve 12 illustrates the compressor performance for an inlet passage height or throat opening of .392 inch. With such diffuser position the best compressor efficiency is attained at

$$\frac{Q}{N}$$

of about .515 and a pressure ratio of about 1.2 indicated by a small circle on the curve 12. With the diffuser positioned for an inlet passage height of .707 a compressor performance is obtained as illustrated by the curve 13 with a maximum efficiency at

$$\frac{Q}{N}$$

of about .146 and a pressure ratio equal to 1. With the diffuser vanes positioned for an inlet passage height of .863 the compressor performance is that indicated by the curve 14 with a maximum efficiency at

$$\frac{Q}{N}$$

equal to .168 and a pressure ratio equal to 1.4. It is noted that with regard to each curve 11 to 14 inclusive the maximum efficiency is attained at a relatively low flow with regard to the particular characteristic and at a point spaced from the minimum air flow where pulsations occur. The spacing is small for small inlet passage heights and somewhat larger for greater inlet passage heights.

The points of best efficiency, that is, the circles on the different curves, are connected by a dotted curve 15 which represents the control characteristic according to my invention. In other words, I provide a control mechanism for positioning the variable diffuser vanes whereby a compressor performance is attained as illustrated by the curve 15. With such a characteristic the pressure ratio, that is, the ratio of impeller pressure rise and diffuser pressure rise, is maintained substantially constant and equal to 1 within a wide range of operation. In the present instance the ratio is maintained substantially constant for

$$\frac{Q}{N}$$

varying from about .08 to .15. From another viewpoint, the pressure ratio is maintained substantially constant within a wide range of movement of the variable diffuser vanes from their mean position indicated in the drawing. In said mean position in the present instance

$$\frac{Q}{N}$$

is about .11. Outside said range the pressure ratio for best efficiency increases gradually as

$$\frac{Q}{N}$$

decreases below .08 and increases respectively above .15.

The control characteristic just described is obtained by an arrangement as illustrated in Fig. 1. This arrangement comprises a centrifugal compressor 16 having a casing forming an inlet 17 and a discharge scroll 18. An impeller with a plurality of vanes 19 is rotatably disposed in the casing. The adjacent vanes 19 form passages with inlets located in the inlet 17 of the casing and outlets for discharging compressed air or like medium into a variable vane diffuser 20. The latter has a plurality of circumferentially spaced vanes of which each has a stationary portion 21 and a variable or adjustable portion 22. Adjacent vanes form diffuser passages with throats defined between the variable portion of one vane and the stationary portion of the adjacent vane. The minimum distance between the stationary portion of one vane and the variable portion of an adjacent vane constitutes the inlet passage height. This inlet passage height or throat is varied upon movement of the variable vane portions. Such movement may be effected in the manner described in the application of M. G. Robinson, Serial No. 482,696, filed April 12, 1943, by means including gears, not shown, and a lever 23 suitably supported on the casing and connected at its outer end to a stem or link 24.

The control mechanism for positioning the stem or link 24 to vary the inlet passage heights or throats of the diffuser passages comprises first means responsive to the ratio of the pressure change or rise across the impeller and the diffuser, and second means for modifying the first means in response to movement thereof. In the present example the control mechanism includes a casing 25 which is substantially hermetically sealed and subject to the diffuser inlet pressure by means of a conduit 26 connecting the casing to the inlet region of one of the diffuser passages. Two bellows 27 and 28 are disposed within and supported on the wall of the casing. The bellows 27 is subject to the impeller inlet pressure by means of a conduit 29 and the bellows 28 is subject to the diffuser outlet pressure by means of a conduit 30. The bellows 27, 28 are pivotally connected to the ends of a lever 31 which is supported on a movable fulcrum 32 by means of a pin 33 projecting through a slot 34 in the lever 31. With the arrangement so far described the lever 31 is subject to the ratio of the pressure rises through the impeller and the diffuser because the bellows 27 is moved in response to changes of the pressure rise through the impeller, the interior of the bellows 27 being subject to impeller inlet pressure and the exterior of the bellows 27 being subject to the diffuser inlet pressure which is assumed to be substantially the same as the impeller outlet pressure. Likewise, the right-hand end of the lever 31 is subject to a force corresponding to the pressure rise through the diffuser, the interior of the bellows 28 being subject to diffuser outlet pressure and the exterior to diffuser inlet pressure.

Movement of the lever 31 is transmitted to the link or stem 24 by means of a hydraulic motor 35 having a piston 36 and being controlled by a pilot valve 37 having an inlet 38 and a pilot valve stem 39. The piston 36 of the motor is secured to the stem 24 and the pilot valve stem 39 is connected to an intermediate point of a follow-up lever 40 which has a right-hand end pivotally connected to the stem 24 and a left-hand end pivotally connected by a link 41 to the lever 31. The link 41 has sliding movement in an opening of the casing 25. The clearance between the opening and the lever 41 should be made small or suitable known means may be provided to reduce or eliminate leakage of air from the casing 25.

The operation of the mechanism so far described is substantially the same as that of the arrangement disclosed in the aforementioned Alford application except that in the present instance a follow-up lever 40 has been added in known manner to assure quick follow-up or restoring action of the pilot valve in response to movement of the motor piston 36. In other words, instead of waiting until the desired pressure ratio has been obtained, the pilot valve in the present instance is restored immediately in response to movement of the motor piston. Such arrangement maintains a constant pressure ratio equal to the ratio of the arms of the lever 31 which in the present example is 1, as long as the bellows 27, 28 have the same effective areas and spring constants. The restoring action of the lever 31 in the present instance is further aided in known manner by the provision of balancing springs 42 and 43 connecting the lever to opposite portions of the casing and upon turning movement tending to restore the lever to its normal position. In order to obtain the control characteristic as illustrated by curve 15 in Fig. 2 I provide means for varying or moving the fulcrum 32 upon movement of the stem 24, more particularly upon movement of the variable diffuser vanes when nearing their end positions, that is, the positions in which minimum and maximum throat areas or inlet passage heights are formed. The means for moving the fulcrum 32 in the present example comprises a link 44 pivotally connecting the link 32 to a slot 45 of a cam 46 or segment secured to the stem 24. In the position shown the variable portions 22 of the diffuser vanes are in their mean position. Likewise, the piston 36 assumes a central position in the motor 35. The link 32 is in an end position in the slot 34 and the link 44 assumes a mid position in the groove or slot 45. Upon movement of the hydraulic motor in either direction from the mid position of the link 44 in the groove 45 the fulcrum 32 remains substantially in the position shown, that is, in the end position in the slot 34. As the motor piston 36 is moved toward the end positions, however, the link **44** is gradually moved towards the left, thereby changing the ratio of the arms of the lever **31** and accordingly increasing the pressure ratio.

During operation a change in inlet or altitude pressure at constant

$$\frac{Q}{N}$$

that is, at constant volume flow per revolution, the diffuser inlet and outlet pressures will vary proportionately to the impeller inlet pressure. Similarly, a change in diffuser outlet pressure due to a change in speed at constant

$$\frac{Q}{N}$$

will cause proportionate changes of the impeller and diffuser inlet pressures. If, however, the diffuser inlet pressure changes at constant speed of the supercharger due to a change in flow, the ratio of pressure rises across the impeller and the diffuser will change. The control mechanism thereupon moves the variable portions **22** of the diffuser vanes into positions to maintain constant said pressure ratio within a wide region from their mean position. As the variable portions **22** move towards their end positions the cam **46** becomes more and more effective and moves the link **32** to increase the pressure ratio at an increasing rate.

Having described the method of operation of my invention, together with the apparatus which I now believe to represent the best embodiment thereof, I desire to have it understood that the apparatus shown is only illustrative and that the invention may be carried out by other means.

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

1. Centrifugal type compressor having an impeller and a variable vane diffuser, and a control mechanism for positioning the diffuser vanes including means responsive to the ratio of the static pressure rise across the impeller to the static pressure rise across the diffuser to maintain said pressure ratio constant over a wide operating range, and other means to modify automatically the action of the first mentioned means to increase said ratio as the compressor nears the limits of its operating range.

2. Centrifugal type compressor having an impeller and a variable diffuser for receiving medium discharged from the impeller, and a control mechanism for automatically varying the diffuser gradually to reduce the ratio of pressure rise across the impeller to the pressure rise across the diffuser in response to increase in volume flow per revolution from no load to an intermediate load and to increase said ratio from an intermediate load to maximum load.

3. Centrifugal type compressor having an impeller and a diffuser with a plurality of adjustable vanes for receiving an impelled medium from the impeller, and a control mechanism for positioning the diffuser vanes, said mechanism comprising means responsive to variations of the ratio of pressure changes across the impeller and the diffuser, hydraulic motor means for positioning the diffuser vanes in response to movement of said ratio responsive means, and other means positioned by the hydraulic motor means for varying the action of the first named means to effect an increase in pressure ratio as the compressor approaches the limits of its operating range.

4. Centrifugal type compressor having an impeller and a diffuser with adjustable vanes for receiving impelled medium from the impeller, and a control mechanism for positioning the vanes comprising a lever, an adjustable fulcrum for supporting the lever, devices responsive to the pressure change across the impeller and the diffuser respectively pivotally connected to the lever, means connecting the lever to the vanes, and means for automatically positioning the fulcrum as the compressor approaches the limits of its operating range.

5. In a centrifugal compressor the combination of an impeller, a variable diffuser, a motor arranged to adjust the diffuser, a control mechanism for the motor including a first device responsive to pressure rise across the impeller, a second device responsive to pressure rise across the diffuser, the control mechanism being arranged to maintain substantially constant the ratio of pressure rise across the impeller to pressure rise across the diffuser, and means positioned by the motor to automatically increase said ratio as the compressor approaches either extreme of its operating range.

6. In a centrifugal compressor the combination of an impeller, a variable diffuser, a motor arranged to adjust the diffuser, and control mechanism for the motor responsive to the ratio of the pressure rise across the impeller to the pressure rise across the diffuser and including a sealed casing, conduit means communicating the static pressure at the diffuser inlet to the interior of the casing, a control lever supported on a variable fulcrum in the casing, a first pressure responsive bellows in the casing connected to the lever and having conduit means arranged to communicate the static pressure at the compressor inlet to the interior of the bellows, a second pressure responsive bellows in the casing connected to the lever and having conduit means arranged to communicate the static pressure at the compressor discharge to the interior of the bellows, and means positioned by the motor for adjusting the variable fulcrum to increase said pressure ratio as the compressor approaches either extreme of its operating range.

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