Jan. 14, 1958 D. K. WARNER 2,819,838

CENTRIFUGAL COMPRESSORS

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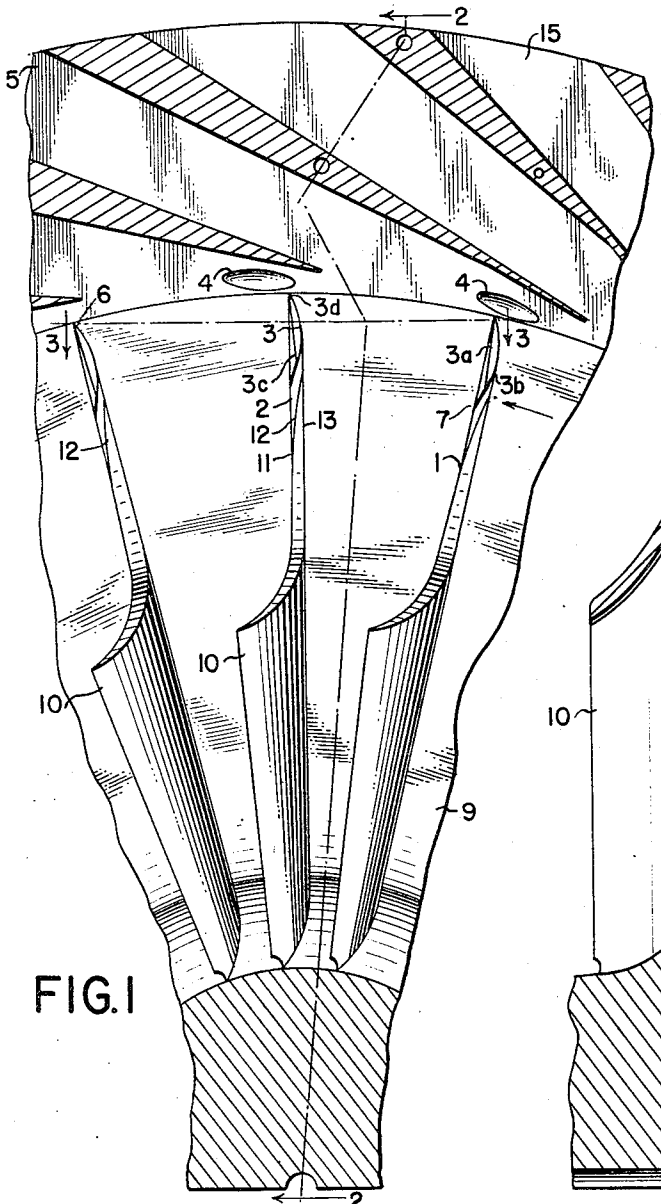


FIG. 1

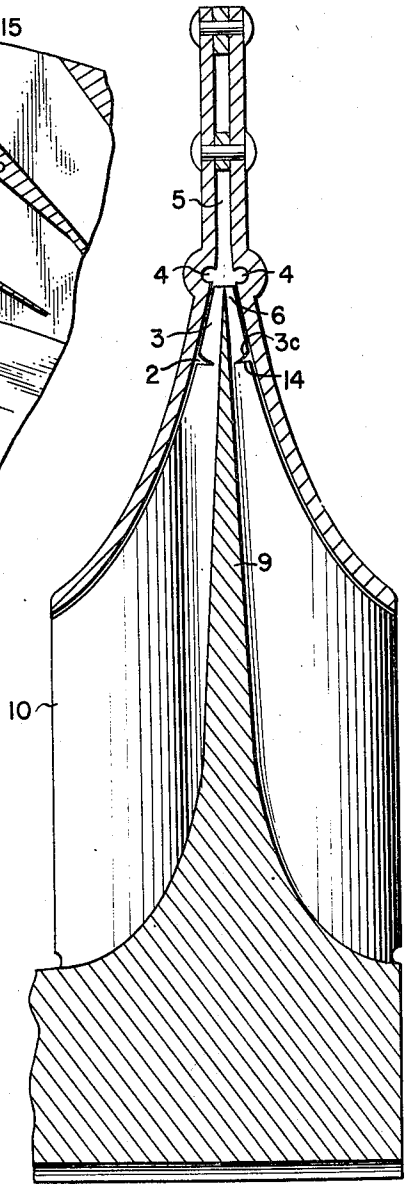


FIG. 2

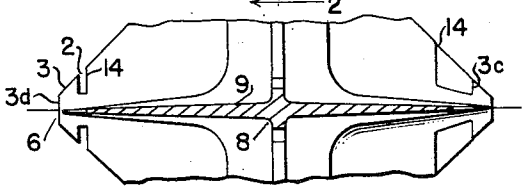


FIG. 3

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CENTRIFUGAL COMPRESSORS

Douglas K. Warner, Sarasota, Fla.

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3 Claims. (Cl. 230—128)

This invention relates to the compression of gases in centrifugal compressors in which the vanes are slotted to permit some of the fastest moving air on the face of a blade to slip back to the reverse side thereof to speed up the stagnant air there and thus give a more uniform flow of air into the diffuser and so reduce the sonic disturbances in the diffuser which reduce efficiency, and, by reflection back to the rotor, cause the latter to prematurely crack. These slots differ from previously disclosed devices in that they are in the trailing portion of the blade instead of its leading portion and instead of reducing the shock loss of the air entering the blade prevent the shock loss in the diffuser from air velocity changes from supersonic flow to reverse flow, ahead of and behind the blades.

The object of my invention is to prevent the diffuser shocks which are normally reflected back to thick blade tips and thence transferred to the highly stressed inner portion of the blade resulting in cracks and short life.

A continuous flow of air outwardly from all parts of the rotor is essential to prevent diffuser shocks. This type of flow requires radial blades with thin outer edges and slots inwardly thereof, a short distance, to correct the reverse flow behind the blades. A further object of the invention is to continually increase the air speed in the passages between rotor blades by sharp narrowing of said passages outwardly to the rotor rim, as opposed to the usual constant speed, and to give the trailing edge of both blade and rotor disc a thin trailing edge. A further object is to prevent sonic disturbances reflected back from the diffuser from destroying the edge of rotor circumference.

This objective is attained in two manners, first by slotting the compressor vanes near their trailing edges to prevent reversal of air flow at the back side of the blade, and second by injecting wet steam into the diffuser passage at a velocity higher than the air velocity leaving the rotor blades and so maintaining flow in the diffuser even if rotor discharge pulsates. The wet steam jet moving only slightly faster than the air entrains air efficiently and the evaporation of the moisture in the steam effects isothermal compression or better depending on the partial pressure of the steam in the air as moisture evaporates. This permits higher pressures with the same power input and gives cool air to an engine for much greater power output.

The compressor is illustrated on the drawing in which:

Figure 1 is an end view of a portion of the compressor above its center line.

Fig. 2 is a section thru 2—2 of Fig. 1 and Fig. 3 is a section through 3—3, Fig. 1.

Similar numbers refer to similar parts in each view.

In Fig. 1 three blades are shown as **1**. Their slots **2** leave an airfoil shaped tip portion **3** sloping slightly forward of radial at a positive attack angle as compared with a straight radial blade thereby increasing air velocity over its forward surface *3a*, as well as creating a high velocity outwardly over the rear of its surface *3b*. The leading edge *3c* of the air-foil-shaped tip portion of the

blade is directed toward the rotor's axis while its trailing or outer portion is directed away from the axis and slightly forwardly at the rotor's circumference **6**.

The blades **1** have the standard forwardly bent side entrance and are deeply slotted at the location of minimum stress near their outer tip portion by their forward portion **11** curving backwardly at **12** till it meets the flat rear side **13** at a sharp edge **14**. The leading edge *3c* of the airfoil shaped tip portion **3** is located forwardly and outwardly of **14** and said tip portion is nearly in radial alignment with blade **1** leaving the slot **2** between them. The air velocity lost in the slot while increasing air velocity at back of blade is more than recovered by this forward slope. Steam jets **4** from each side of diffuser passage **5** discharge very wet steam into said passage immediately adjacent the rim of said rotor.

While the conventional compressor develops cracks near the blade roots when operated at speeds attaining 4½ ratios of compression this is due to the sonic vibrations reflected back from the diffuser where they are created by the sharp variations in velocity of air at front and back of each vane. Both the wet steam jet and the slotted vanes help to reduce these sharp sonic disturbances with the result that the fan may be safely operated at higher speeds and with thin trailing edges of web and blade. The thin trailing edges further enhance the flow conditions increasing efficiency by the reduction of disturbance. The higher permissible R. P. M. gives an air speed nearer the steam speed so improving entrainment efficiency. The steam added to the air is useful in engines in that it permits higher compression without knock and permits using a premixed fuel-air charge with higher than the usual diesel engine pressures. In the double flow compressor shown, wet steam jets entering oppositely from both sides meet in the center of the passage and thence flow straight down the center thereof permitting little erosion of the side walls, and in the single flow compressor, not shown, the diffuser has an axial-radial slope in order that the steam jets travel through the center of passage. (Instead of the usual straight radial flow from the impeller, the air flows slightly axially and the steam jets entering from the air input side move down the center of the diffuser passage.)

It is not essential that steam jets be directed into all diffuser passages, it being preferable to direct them only into those passages which carry air to the driving engine. Thus a stall which often starts in one passage and works around from passage to passage will be stopped when it reaches the steam jetted passage. In slotting the vanes I prefer to slot them diagonally as shown at **7** and to extend the slot only to the edge of the large fillet **8** on the forward face of blade where it joins disc **9**.

This slot being made where the blade stress is least and where disc and blades are rapidly thinning does not affect the rotor strength. Steam jets entering from both sides keep water in center of passages.

In the diffuser **5** are passages **15** of gradually increasing cross sectional area outwardly where both air and steam are slowed down with resulting pressure increase.

I claim:

1. A centrifugal compressor comprising a housing, a centrifugal impeller mounted rotatably in said housing, said impeller having outwardly extending blades and said blades having sharp leading edge portions directed with rotation of said impeller and radially extending portions attached to said leading edge portions, said radial portions having rearwardly outwardly inclined slots, said slots being located adjacent to the outer ends of said radial portions of said impeller blades and said slots being disposed at the point of minimum stress in said blades whereby said slots provide an outward high velocity air flow stream adjacent the down-stream side of said blade

tip portion, said housing having a diffuser peripherally disposed about said impeller and said diffuser comprising a plurality of forwardly inclined walls having sharp leading edges wherein adjacent walls form downstream outwardly diverging flow passages, a plurality of downstream outwardly inclined nozzles in said diffuser adjacent the periphery of said impeller and located between the said adjacent forwardly inclined walls whereby wet steam flowing through said nozzles at a higher velocity than the air leaving the tips of said blades increases the air velocity and aids said slots in keeping the air velocity uniform across the diffuser passage so eliminating shock waves in the diffuser and the reflection of those waves back to the rotor periphery whence in other compressors it is carried back to the blade roots cracking same.

2. In a centrifugal compressor a housing including a diffuser, a rotor including a web portion mounted within said housing, centrally of said diffuser, blades mounted radially on said web portion, said blades having thin outer trailing edges, the outer portion of each of said blades being separated from their inner portion and a slot formed therebetween, said outer portion of said blades forming an airfoil shaped section approximating the standard cambered flat-bottomed-wing airfoil having a leading edge bluntly rounded and directed inwardly and located forwardly relative to said rotor's rotative direction and outwardly of the trailing edge of the inner portion of said blade, said inner portion being swept back and outwardly terminating in a thin trailing edge in line with the blade's rear surface, said outer portion being the portion of the said blade which is radially outwardly

beyond the inner portion with said slot therebetween, and said outer portion commencing at location of minimum stress in said rotor close to the rim thereof, whereby air flows rearwardly outwardly through the slot so preventing inward flow of air behind the tip portion of said blade and whereby the resulting sonic bangs in said diffuser are avoided which in blades without such outwardly located slots are transmitted back through said blades to the inner highly stressed portions thereof causing cracks.

3. A compressor as set forth in claim 2 in which said airfoil-shaped tip portion has a positive attack angle with respect to the radial direction of the inner portion of a blade whereby velocity lost by air passage through said slot is regained.

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