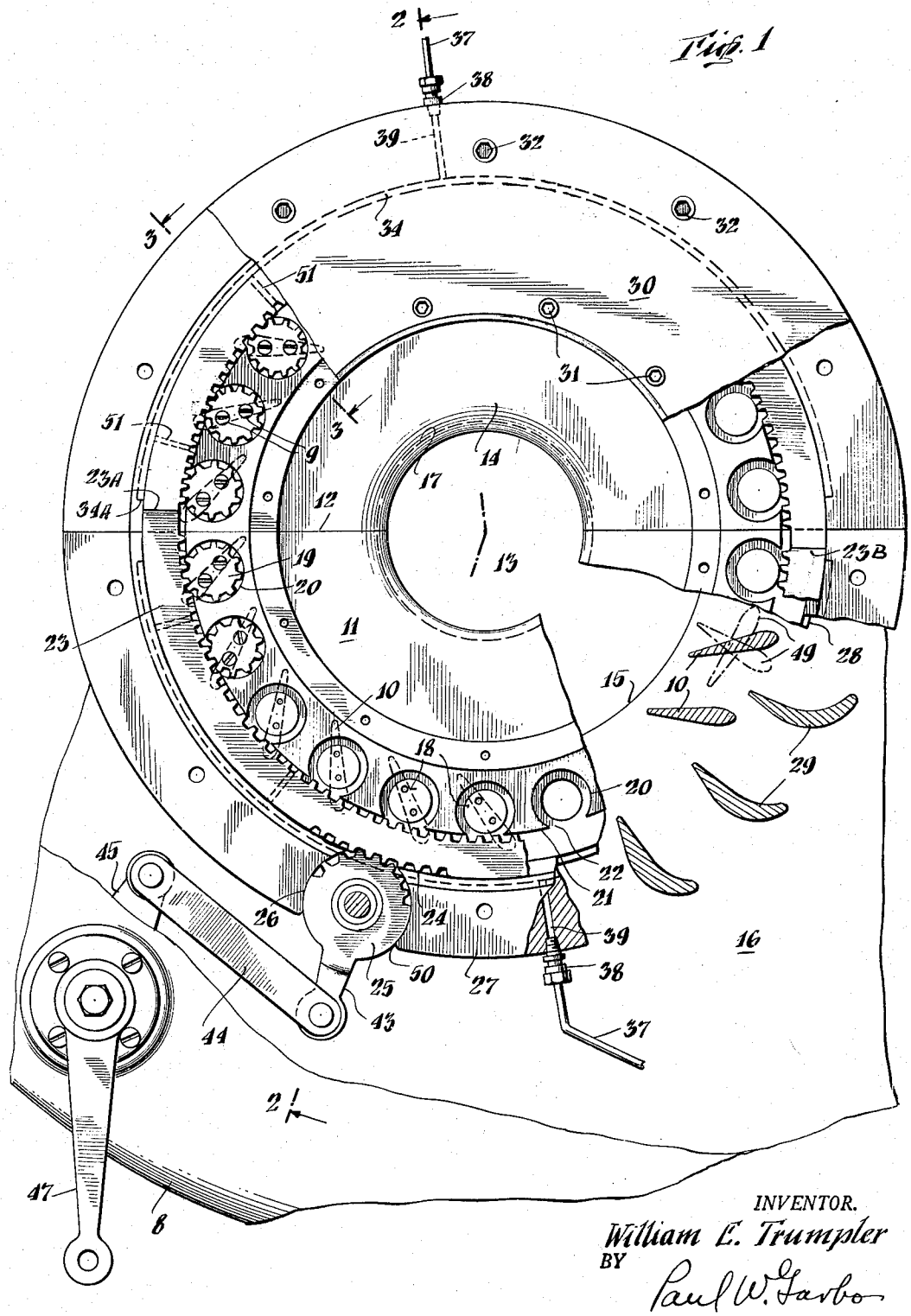
Feb. 7, 1956 W. E. TRUMPLER 2,733,853

MOVABLE GUIDE VANES FOR CENTRIFUGAL COMPRESSORS

Filed May 28, 1952 2 Sheets-Sheet 1

Fig. 1



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Filed May 28, 1952 2 Sheets-Sheet 2

Fig. 2

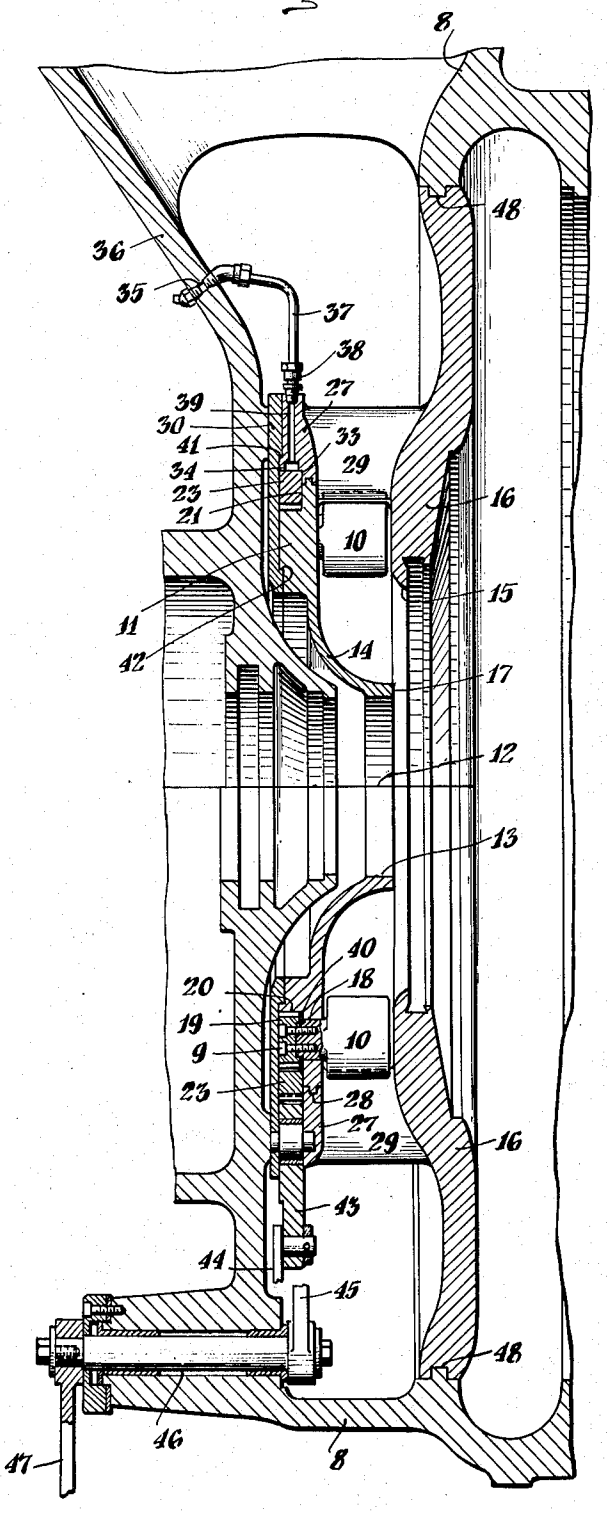
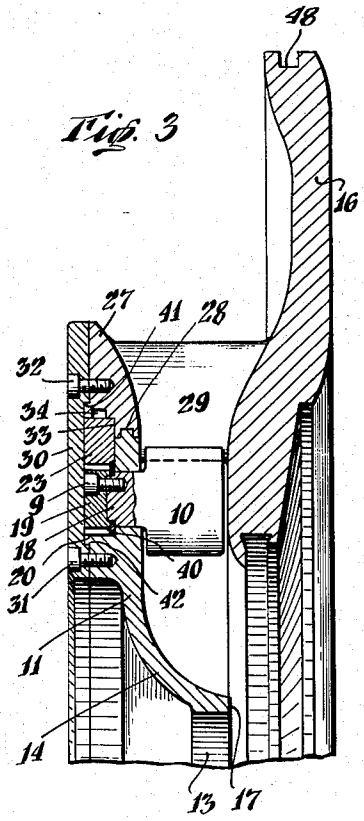


Fig. 3



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MOVABLE GUIDE VANES FOR CENTRIFUGAL COMPRESSORS

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10 Claims. (Cl. 230—114)

The present invention relates to centrifugal compressors and, more particularly, to movable inlet guide vanes which direct the gas to be compressed into an impeller of the centrifugal compressor, the vanes being movable or adjustable for the purpose of controlling the discharge pressure and capacity of the compressor. The movable guide vanes of this invention are especially useful in centrifugal compressors which are driven by a constant speed machine, e. g., a synchronous motor.

Many prior proposals have been made for the mechanism required to move the inlet guide vanes and thus modify the capacity of an impeller for varying conditions of operation of the centrifugal compressor. However, these prior mechanisms have suffered from several disadvantages, principally, complexity and bulkiness of the mechanism which have increased the cost and size of centrifugal compressors, and lubrication troubles in the form of contamination of the compressed gas by the lubricant and inadequate lubrication of all parts of the moving mechanism.

A principal object of this invention is to provide a compact and reliable mechanism for moving and positioning the inlet guide vanes ahead of an impeller of a centrifugal compressor.

Another important object is to provide such a mechanism in which all moving parts are properly lubricated.

A further important object is to ensure that the lubricant applied to the moving parts of the mechanism will not leak into the gas passages between the movable vanes where the high-velocity gas stream would carry the lubricant through the machine and contaminate the gas.

Still another object is to provide a movable guide vane assembly with a sealed-in lubrication system; it is an advantage of the invention that the vane assembly is adapted for ready insertion in the gas inlet channels in the casings of centrifugal compressors.

Other objects and advantages of the invention will be apparent from the following description thereof.

The invention may be more readily understood by reference to the accompanying drawings in which similar reference characters refer to similar parts and in which:

Figure 1 is a view of the back of the mechanism of this invention; in said view, portions of the mechanism are shown broken away to illustrate more clearly the structure of the mechanism at several spaced planes therein;

Figure 2 is a sectional view taken along the line 2—2 of Figure 1; in this view, the mechanism is shown disposed within the inlet portion of the casing of the centrifugal compressor, i. e., in position for operation in conjunction with the operation of the centrifugal compressor; and

Figure 3 is a partial sectional view taken along the line 3—3 of Figure 1 but on a larger scale than that used in Figure 2; in Figure 3, the mechanism is shown removed from the casing of the centrifugal compressor.

In accordance with this invention, a plurality of movable inlet guide vanes **10** are mounted in spaced relation

to each other and in a circular arrangement on a disk **11** which is normally split in half along its horizontal diameter **12** and which has a circular opening **13** at its center so that the two halves of disks **11** with the mounted movable vanes **10** can be fitted together around the shaft (not shown) of the centrifugal compressor. Disk **11** is curved at **14** in the vicinity of its central opening **13** so that the gas flowing from the outer periphery of the disk **11** toward the shaft of the centrifugal compressor is guided by the curved portion **14** into the inlet or eye of the adjacent impeller (not shown). Referring to Figure 2, the eye of the impeller would be disposed adjacent the annular opening extending between the circular edge **15** of inlet wall **16** and rim **17** of disk **11**. Each of the movable vanes **10** has a rotatable shaft **18** which passes through disk **11** and provides the mounting of the movable vane **10** on disk **11**. Each movable vane shaft **18** passing through disk **11** terminates in a pinion **19** which is fastened by a pair of screws **9** to vane shaft **18**. A washer **40** may be placed around each vane shaft **18** between its pinion **19** and disk **11**. Each movable vane pinion is set in a circular cut-out **20** in the side of the disk **11** opposite the side from which the movable vanes **10** project. For brevity, hereinafter the side of disk **11** with the vanes **10** will be referred to as the face while the opposite side will be called the back of disk **11**. The back of disk **11** is also cut-away along its entire outer periphery to an extent that this peripheral cut-away **21** removes a portion of the circumferential wall of each circular cut-out **20** in back of the disk **11**, thus establishing fluid communication between the peripheral cut-away **21** and the several circular cut-outs **20** as shown at **22** in Figure 1. A split, internal ring gear **23** fits in the peripheral cut-away **21** and its teeth mesh with the teeth of the pinions **19** in the several circular cut-outs **20**. As shown at **23A** in Figure 1, one end of the bottom half of split ring gear **23** projects a short distance into the top half of rim section **27** while the top half of internal ring gear **23** similarly, as shown at **23B**, has one end projecting a short distance into the lower half of rim section **27** to maintain alignment between the top and bottom halves of rim section **27**. Several teeth on each half of internal ring gear **23** are removed from the portion of the gear projecting beyond the horizontal split **12** of the vane assembly; this prevents the teeth of pinions **19**, adjacent to split **12** from locking with internal ring gear **23** and making it difficult to separate one-half of the vane assembly from the other half.

The split ring gear **23** in either the top or the bottom half (shown in Figures 1 and 2 in the bottom half) is provided on its outer periphery with a plurality of gear teeth **24** which mesh with the teeth of control pinion **25**. The control pinion **25** is set in a circular cut-out **26** in rim section **27** which meets the outer periphery of disk **11** in a tongue-and-groove joint **28**. Rim section **27** is desirably provided with a plurality of fixed guide vanes **29** to direct the gas stream uniformly toward the movable vanes **10**. It is also advisable to stagger the circumferential arrangement of fixed vanes **29** relative to that of movable vanes **10** and to have vanes **29** project radially inwardly as far as possible without interfering with the movement of vanes **10**, as can best be seen in Figure 1. Desirably, the outer faces of rim section **27** and adjacent inlet wall **16** are smoothly curved to provide a tapered channel which will guide the gas to be compressed without undue turbulence through the two rings of fixed vanes **29** and movable vanes **10** toward the eye of the adjacent impeller (not shown). Generally, each half of rim section **27**, its fixed vanes **29** and half of inlet wall **16** are formed as a single casting. Thus, inlet wall **16** which is held in compressor casing **8** at tongue-and-groove joint **48** supports the entire movable vane as-

sembly within the compressor casing by means of fixed vanes 29 which are joined to both inlet wall 16 and rim section 27.

The split rim sections 27 meet the respective halves of split disk 11 in tongue-and-groove joint 28 and are held in their joined relation by the halves of the split annular back plate 30; screws 31 fasten back plate 30 to disk 11 and screws 32 hold the back plate 30 and rim section 27 together. The back of rim section 27 has an inner peripheral cut-away 33 which complements the outer peripheral cut-away 21 of disk 11 so that together the cut-aways 21 and 33 form the annular channel in which internal ring gear 23 is fitted and held therein by back plate 30. The cut-away 33 of rim section 27 includes a groove 34 to provide a lubricant channel around the circumferential extent of split ring gear 23. This lubricant channel 34 is blocked off at horizontal split 12, as indicated at 34A in Figure 1, to prevent lubricant draining from the upper half of rim section 27 to the lower half and also prevent escape at horizontal split 12. Lubricant is supplied by way of fitting 35 which passes through the wall 36 of the compressor casing and which is connected by tubing 37, fitting 38 and passage 39 to channel 34. Passage 39 is a hole drilled radially through rim section 27. As shown in Figure 1, lubricant is supplied to channel 34 at the top and bottom of rim section 27. A number of radial holes 51 in internal ring gear 23 form passages through which lubricant flows to the teeth of ring gear 23 and thence to pinions 19. Due to the close assembly clearances employed, the movable vane mechanism is a self-contained, grease-packed unit with a minimum of make-up lubricant required over a long period of time.

From the foregoing description, it is evident that disk 11, rim section 27 and back plate 30 are tightly fastened together and completely encase the ring gear 23 and all the movable vane pinions 19. The lubricant filling channel 34 wets all portions of internal ring gear 23 and, since the circular cut-outs 20 which hold vane pinions 19 are in open communication, as shown at 22 in Figure 1, with peripheral cut-away 21 in which ring gear 23 is set, the lubricant flows into the circular cut-outs 20 and bathes the vane pinions 19. The seepage of lubricant from circular cut-outs 20 along the rotatable shafts 18 of movable vanes 10 to the face of disk 11 is impeded by washers 40. Similarly, the tongue-and-groove joint 28 between disk 11 and rim section 27 keeps the lubricant from oozing to the face of disk 11 where it would contaminate the gas to be compressed. Likewise, it is advisable to employ annular shoulders 41 and 42 on the inner side of back plate 30 which fit snugly into complementary annular depressions, respectively, in rim section 27 and disk 11 so as to prevent the lubricant from seeping through the joints between the back plate 30 and rim section 27 and between back plate 30 and disk 11. Control pinion 25 is also sealed in circular cut-out 26 of rim section 27 by back plate 30; the lubricant which flows around internal ring gear 23 reaches control pinion 25 and is held in circular cut-out 26 by the tight fit between control pinion 25 and the walls of cut-out 26. Furthermore, the movement of control pinion 25 is so limited that its teeth never pass the corners 50 of cut-out 26, thereby retaining the lubricant. In general, the clearance between moving parts of the vane assembly which are to retain the lubricant is of the order of 0.005 inch while the clearance between moving parts which are to permit the passage of lubricant is of the order of 0.012 inch.

Control pinion 25 has an arm 43 which is linked by bar 44 to inner crank 45 which in turn is keyed into one end of crankshaft 46. Crankshaft 46 passes through the casing wall of the centrifugal compressor and, exteriorly thereof, is keyed to an outer crank 47 which is linked to manual or automatic means (not shown) for moving the entire movable vane assembly in response to varying conditions of operation of the centrifugal compressor. Thus, partial rotation of outer crank 47 turns crankshaft 46 and inner crank 45; the rotative movement of inner crank 45 imparts movement to bar 44 which causes partial rotation of control pinion 25. Since the teeth 24 of ring gear 23 mesh with the teeth of control pinion 25, clockwise movement of control pinion 25 imparts counterclockwise movement to ring gear 23 and vice versa. In turn, clockwise movement of internal ring gear 23 causes clockwise movement of the several movable vane pinions 19 and vice versa. As shown in phantom at 49 in Figure 1, the foregoing movements can vary the position of movable vanes 10 from a wide open position of substantially radial alignment to one approximately at right angles thereto representing a fully closed position; the movable vanes 10 are actually shown at a setting intermediate these extreme positions. In some cases, an angle of turn greater than a right angle may be used to rotate the vanes from a fully closed position to past the radially open position. Under operating conditions, the gas stream imposes an eccentric load on each vane 10. The force couple brought about by this loading is opposed by the force couple resulting from the thrust of washer 40 bearing on disk 11 and the thrust of pinion 19 bearing on back plate 30. This relieves shaft 18 of binding in disk 11. Also, members 47, 46, 45, 44, 43 and 25 are connected through ring gear 23 to pinions 19 to provide maximum turning force when movable vanes 10 are near the closed position.

From the foregoing description it is clear that the present invention provides a compact and reliable mechanism for moving a set of inlet guide vanes in a centrifugal compressor, the mechanism having the important features that all the rotatable elements therein are bathed in lubricant but the lubricant is sealed in within the mechanism so that it cannot reach the gas passages in the centrifugal compressor. It is well to note that the mechanism of this invention can be built so compactly that it will fit in the inlet annular passage within the casing of nearly any conventional centrifugal compressor.

Inasmuch as modifications and variations of the mechanism shown in the drawings and described hereinbefore for the purpose of better illustrating the present invention will be apparent to those skilled in the art without departing from the spirit or scope of the invention, only such limitations should be imposed as are indicated by the appended claims.

What is claimed is:

1. In a centrifugal compressor having a casing provided with a fluid inlet port and a communicating annular channel leading to an impeller, the improvement of a movable guide vane assembly disposed in said annular channel, which comprises a disk with a central aperture and a plurality of circular openings spaced from one another along a circle around said central aperture, a guide vane with a rotatable shaft extending from a lateral edge thereof positioned at each of said openings so that said guide vane projects outwardly from the face of said disk and its shaft is disposed in one of said openings, a pinion attached to the end of each of said shafts at the back of said disk, an internal ring gear at the back of said disk in driving engagement with each such pinion, said internal ring gear being provided with gear teeth on its outer periphery, a rim section provided with a plurality of spaced, fixed guide vanes and abutting the outer peripheries of said disk and said internal ring gear, a groove in said rim section contiguous the outer periphery of said internal ring gear, a fluid passage extending through said rim section for supplying lubricant from an exterior source to said groove, a cut-out in the back of said rim section, a close fitting control pinion set in said cut-out, said control pinion being in driving engagement with said gear teeth on the outer periphery of said internal ring gear and having an arm projecting from said cut-out beyond the outer periphery of said rim section, and a sealing plate

attached to the backs of said disk and said rim section, thereby completely enclosing said internal ring gear and the pinions in driving engagement therewith.

2. The movable guide vane assembly of claim 1 wherein the pinions at the ends of the rotatable shafts are set in close fitting recesses in the back of said disk.

3. The movable guide vane assembly of claim 1 wherein the rim section abuts the outer periphery of said disk in a tongue-and-groove joint.

4. The movable guide vane assembly of claim 1 wherein the fixed guide vanes extend from said rim section to an inlet wall which fits in said casing in front of an impeller, said fixed guide vanes being joined to both said rim section and said inlet wall.

5. In a centrifugal compressor having a casing provided with an annular channel ahead of an impeller, the improvement of a movable guide vane assembly disposed in said annular channel, which comprises a disk with a central aperture and a plurality of circular openings spaced from one another along a circle around said central aperture, a guide vane with a rotatable shaft extending from a lateral edge thereof positioned at each of said openings so that said guide vane projects outwardly from the face of said disk and its shaft is disposed in one of said openings, a pinion attached to the end of each of said shafts at the back of said disk, an internal ring gear at the back of said disk in driving engagement with each such pinion, said internal ring gear being provided with gear teeth on its outer periphery, a control pinion in driving engagement with said gear teeth on the outer periphery of said internal ring gear and having a motivating arm projecting beyond the outer periphery of said movable guide vane assembly, means attached to said disk and forming therewith a substantially fluid-tight enclosure containing said internal ring gear and the pinions in driving engagement with said internal ring gear, and a fluid passage for supplying lubricant from an exterior source to said enclosure.

6. The movable guide vane assembly of claim 5 wherein a plurality of fixed guide vanes hold said vane assembly in spaced relation to an inlet wall which fits in said casing ahead of an impeller.

7. The movable guide vane assembly of claim 5 which is split along a diameter thereof, each half of the split vane assembly having one end of its half of said internal ring gear protruding out of the plane of the split, the protruding end being without gear teeth.

8. In a centrifugal compressor having a casing provided with an annular channel ahead of an impeller, the improvement of a movable guide vane assembly disposed in said annular channel, which comprises a disk with a central aperture and a plurality of circular openings spaced from one another along a circle around said central aperture, a guide vane with a rotatable shaft extending from a lateral edge thereof positioned at each of said openings so that said guide vane projects outwardly from the face of said disk and its shaft is disposed in one of said openings, a pinion attached to the end of each of said shafts at the back of said disk, an internal ring gear at the back of said disk in driving engagement with each such pinion, means associated with said internal ring gear for effecting rotative movement of said internal ring gear relative to said disk, means attached to said disk and forming therewith a substantially fluid-tight enclosure containing said internal ring gear and the pinions in driving engagement with said internal ring gear, and a fluid passage for supplying lubricant from an exterior source to said enclosure.

9. The movable guide vane assembly of claim 8 wherein the pinions at the ends of the rotatable shafts are set in close fitting recesses in the back of said disk.

10. The movable guide vane assembly of claim 8 which is split along a diameter thereof, each half of the split vane assembly having one end of its half of said internal ring gear protruding out of the plane of the split, the protruding end being without gear teeth.

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