United States Patent [19]
Canova et al.

[11] **3,773,430**
[45] **Nov. 20, 1973**

[54] **GAS COMPRESSOR**

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[73] Assignee: **Ingersoll-Rand Company,** New York, N.Y.

[22] Filed: **Mar. 17, 1972**

[21] Appl. No.: **235,501**

[52] **U.S. Cl.** .... **415/104,** 415/131, 415/199 R, 415/216, 416/215, 415/138

[51] **Int. Cl.** **F01d 3/00,** F01d 5/26

[58] **Field of Search** .... 415/131, 138, 219, 415/199 R, 217, 218, 104

[56] **References Cited**

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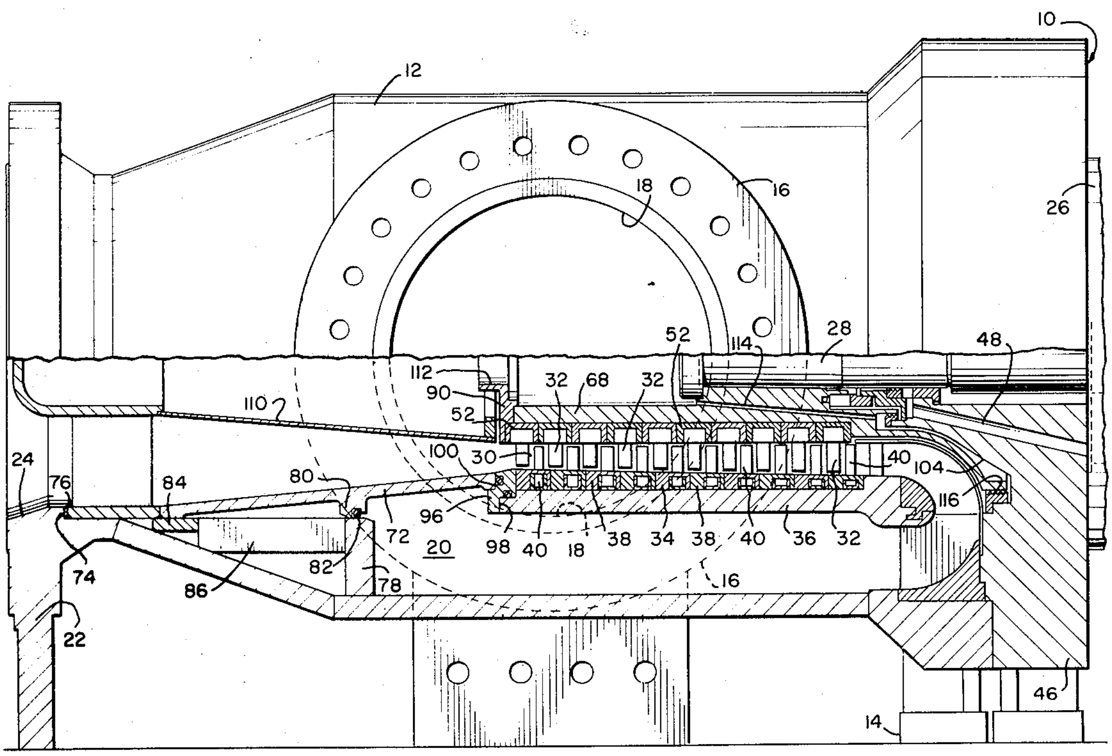
Primary Examiner—Henry F. Raduazo
Attorney—David W. Tibbott et al.

[57] **ABSTRACT**

The gas compressor is of the axial flow type, having a plurality of stages of compression, and an overhung rotor. Turbine nozzle-type stator vanes are used, resulting in a foreshortening of stage axial length, and eliminating a requirement for guide vanes at the diffuser entrance. A housing and frame enclose and support the working elements of the compressor, the elements being so supported and enclosed as to allow for relative movements of the housing without causing distortion of said elements.

15 Claims, 14 Drawing Figures



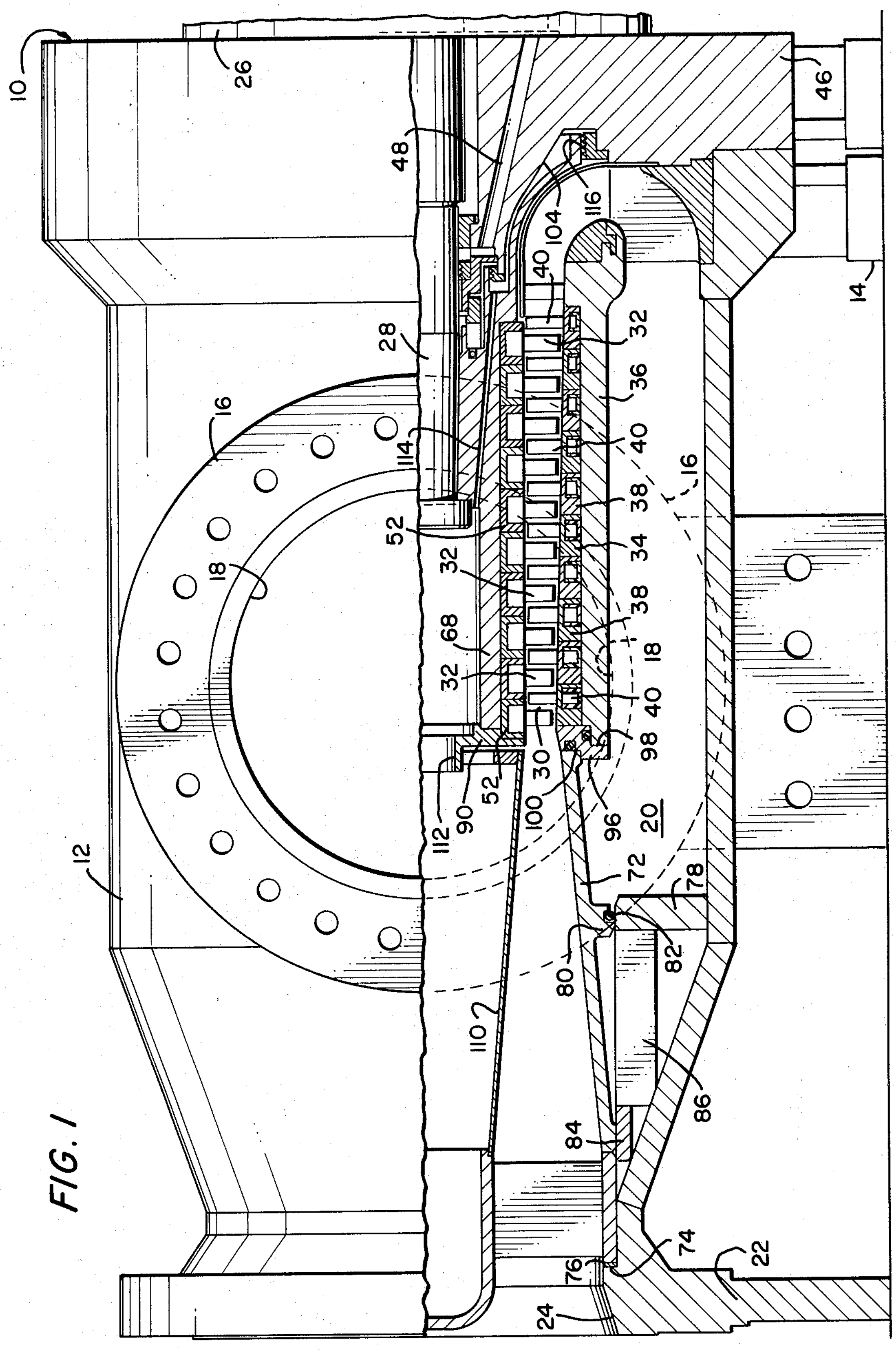

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FIG. 1

FIG. 3

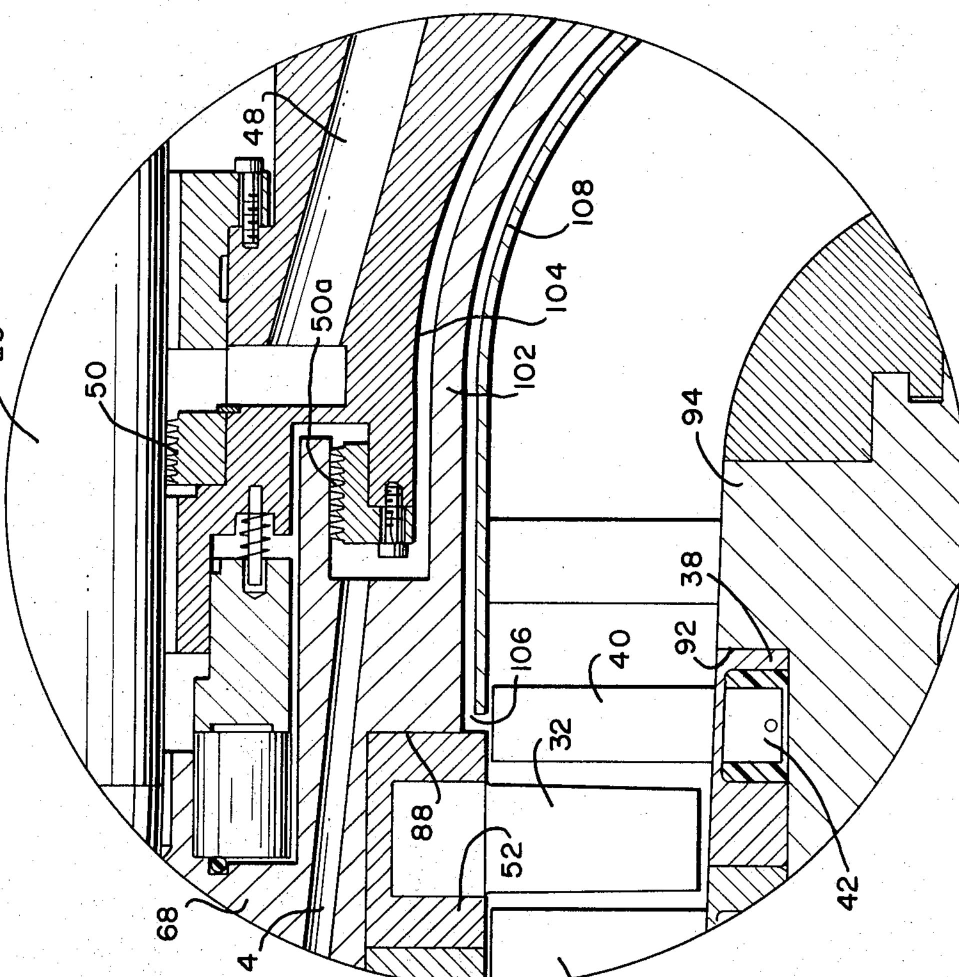


FIG. 2

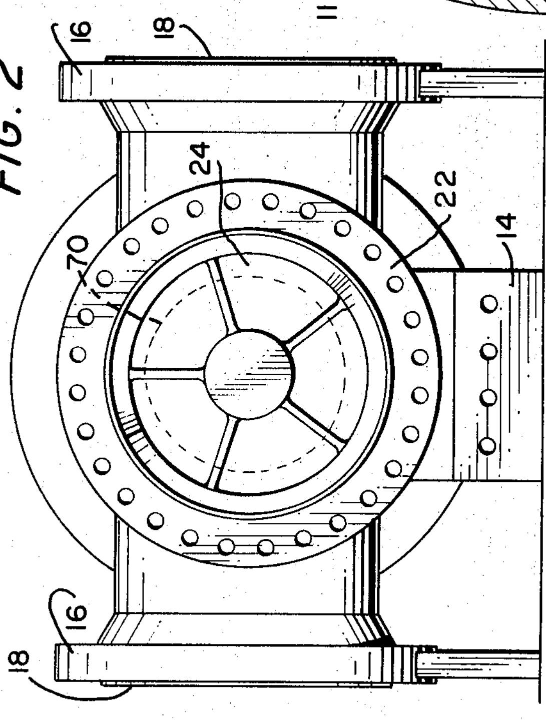
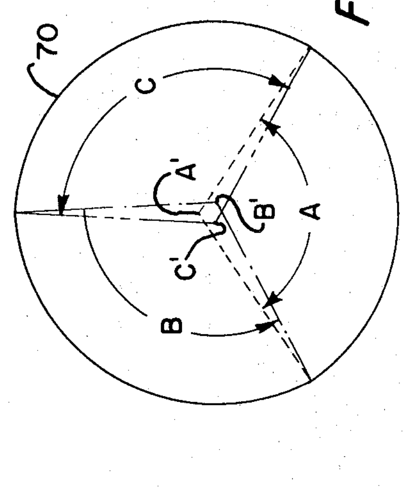


FIG. 12



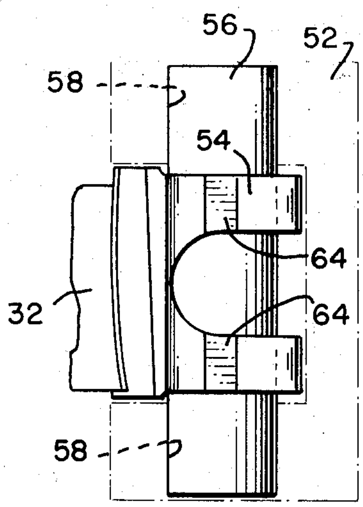
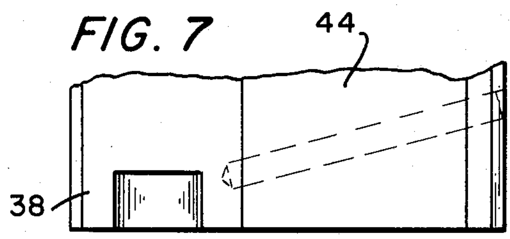


FIG. 4

FIG. 7



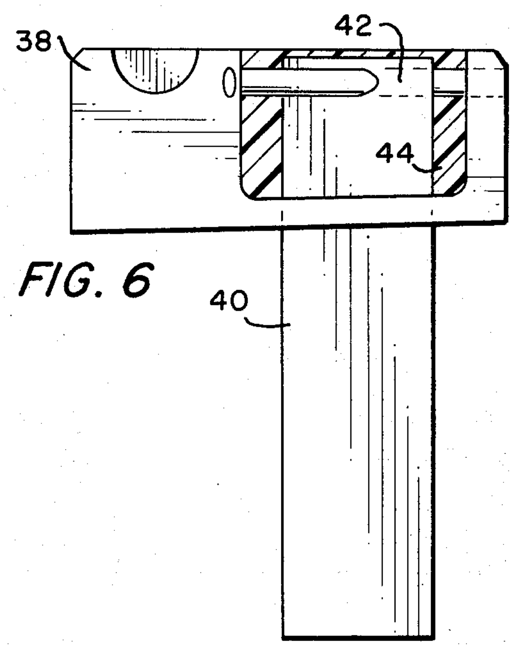


FIG. 6

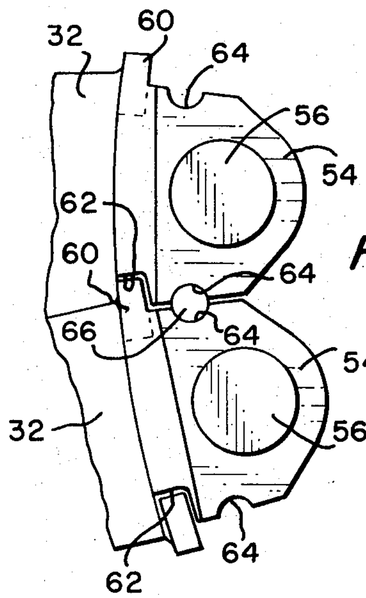


FIG. 5

PRIOR ART

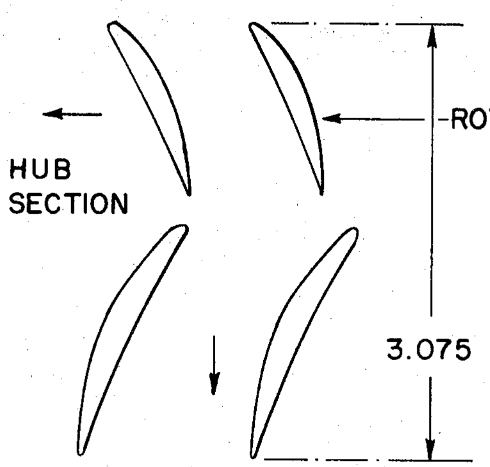


FIG. 8

PRIOR ART

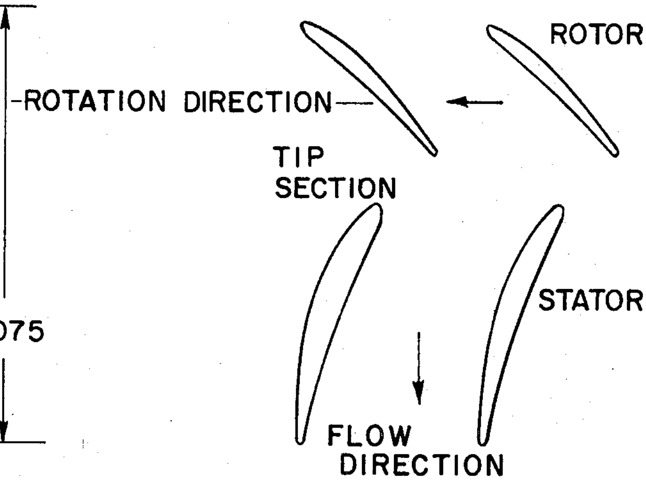


FIG. 9

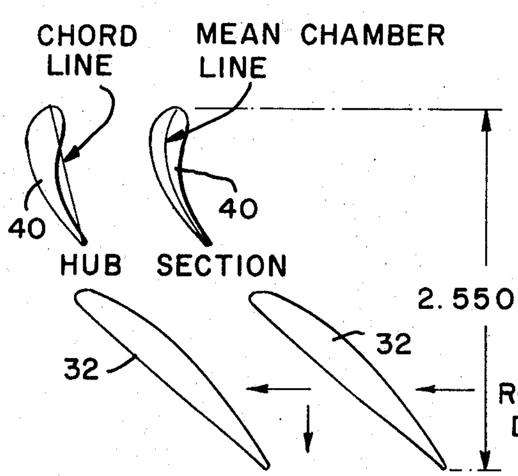


FIG. 10

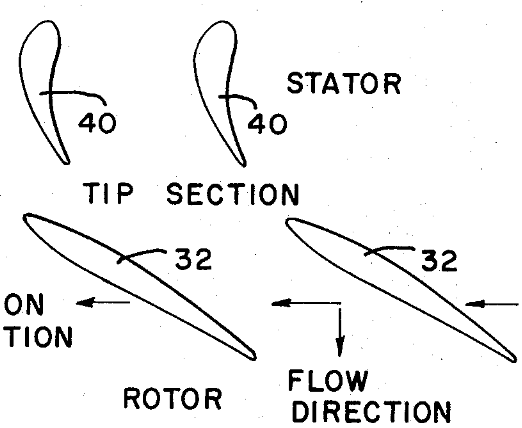


FIG. 11

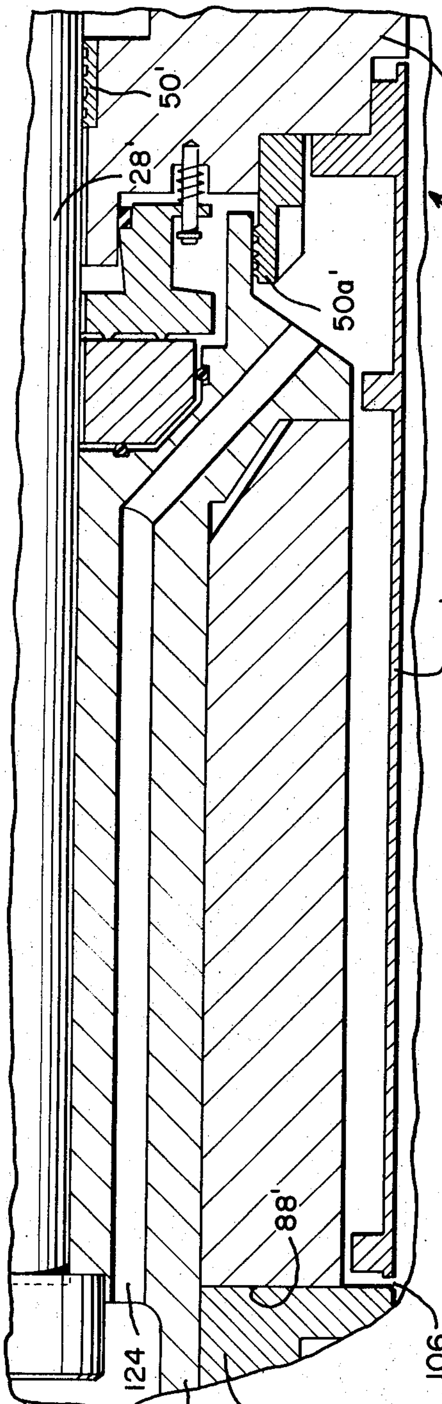

50'
46'
28
10'
50a'
108'
88'
124
106
68
52

FIG. 14

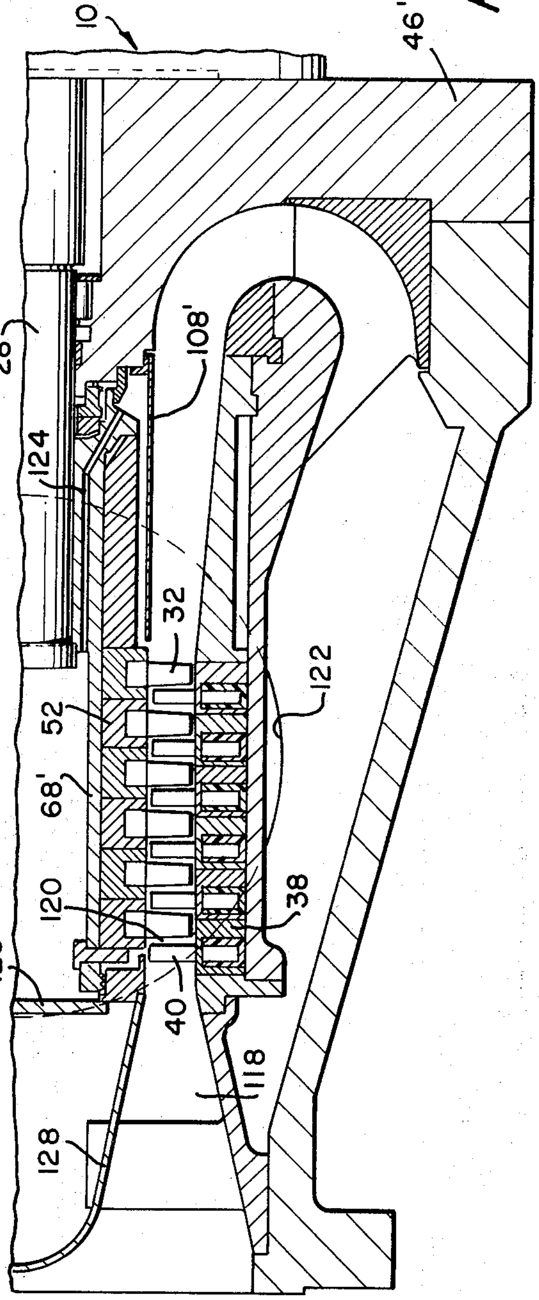

10'
46'
28'
108'
124
32
122
52
68'
120
38
126
40
118
128

FIG. 13

GAS COMPRESSOR

This invention pertains to gas compressors, and in particular to gas compressors of the axial flow type having a plurality of stages of compression.

Single or multistage axial flow compressors could be especially useful for high density gases and in particular for gas pipeline applications where inlet pressures of 600–1200 psi are encountered, and process gas applications involving high inlet temperatures.

In these areas, the axial flow compressor would have the following advantages as compared to centrifugal machines: a) higher efficiency potential, b) higher rotating speed, c) smaller physical size, and d) simpler and quicker rerating possibilities as only blade height and number of stages would have to be altered.

Known types of axial flow compressors, for all the possible uses thereof, are limited in design however. The present state of the art of axial flow compressors is inhibited because of the high bending loads which act on the rotating and stator blade systems. Typically, these blade systems are of the conventional 50 percent reaction blading type such are used in most industrial and aircraft type axial flow machines.

The conventional 50 percent reaction blading axial flow compressors, further, require an excessive stage length which warrants foreshortening that the overall machine length might be reduced, and also to facilitate the use of single rotor bearing and shaft seal arrangements, rather than two of each to accommodate the extendedly lengthy stages.

It is an object of this invention to set forth an improved gas compressor, of the axial-flow type, which eliminates the disadvantages, just noted, which obtain in known axial-flow gas compressors.

It is another object of this invention to teach an improved gas compressor, of the axial-flow type, which comprises means for isolating the working elements thereof, i.e., the rotor, shaft, etc., from pressure- or temperature-induced distortion and/or misalignment of the compressor housing and base.

Another object of this invention is to set forth a gas compressor comprising a housing defining a compression chamber therewithin; said housing having means for admitting gas into said chamber and means for discharging compressed gas from said chamber; radially bladed rotor means for compressing gas within said chamber; shaft means rotatably mounting said rotor means within said chamber about an axis; vaned stator means within said chamber replaceably fixed to said housing and cooperative with said rotor means for compressing gas within said chamber; said chamber having an annular configuration and extending along said axis; wherein said rotor means extends coaxial with said stator means; and said shaft means support said rotor means at only one axial end of said rotor means, providing cantilevered mounting of said rotor means within said chamber; and further including means dispoed between said housing and at least one of said rotor, stator, and shaft means for isolating said rotor and shaft means from statically-induced distortions of said housing.

Further objects and features of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying figures, in which:

FIG. **1** is an axial view, partly in cross-section, of an embodiment of a gas compressor, according to the invention;

FIG. **2** is an end view, in elevation, of the exit end of the FIG. **1** embodiment;

FIG. **3** is an enlarged view of area A of FIG. **1**;

FIGS. **4** and **5** are side and end views illustrative of the rotor blade and mounting ring arrangements;

FIGS. **6** and **7** are side and plan views depicting the stator vane and mounting ring arrangements;

FIGS. **8, 9, 10** and **11** diagrammatically compare the hub and tip cross-sections of stator vanes and rotor blades as known in prior art with those taught by the invention;

FIG. **12** is a schematic representation of the outside diameter of the rotor shaft extension, the diameter being generated from different radial centers and defining a plural-lobe surface; and

FIGS. **13** and **14** depict an alternate embodiment of a gas compressor, according to the invention, the first being a partial, axial, cross-sectional view thereof, and the second being an enlarged view of area B of FIG. **13.**

As shown in the figures, the novel gas compressor **10** comprises a housing **12** having a base **14** for supporting the housing thereupon. A pair of oppositely disposed gas inlet flanges **16** are mounted to each side of the housing, the flanges defining inlet ports **18** which open on a chamber **20** defined within the housing. At the axial outlet end of the compressor is mounted a gas discharge flange **22** having an outlet port **24** formed therein.

Upstream of the inlet end are carried coupling means and a bearing housing assembly (not shown), the two being supported in a casing **26** which is fixed to the compressor base **14.** An over-hung, axially-extending rotor and shaft assembly **28** is rotatably supported at but one axial end in the bearing housing, for rotary, gas-compressing movement within a compression chamber **30,** and includes pluralities of radially-disposed blades **32.** A vaned stator **34,** concentrically disposed about the rotor and shaft assembly, is mountedly supported within the compressor housing, by means of a cylindrical housing **36** which carries vane mounting rings **38** therewithin. The stator **34** comprises a plurality of such vane mounting rings in juxtaposition, each of which has fixed therein a plurality of vanes **40.** All of the vanes **40** are of uniform length; however, the stator mounting rings **38** are of uniformly varying cross-section, from the inlet end to the outlet end of the compression chamber so that, toward the outlet end, progressively less of the vanes **40** protrudes into the compression chamber **30.** Each vane **40** is pinned into its respective mounting ring **38** and, further, each vane head **42** is set in an elastomer **44** for the purpose of damping vane vibration.

The housing base **14** comprises a vertical plate **46** which has passageways (not shown) formed therein for the admittance of ambient atmosphere as a sealant and also for introducing lubricating oil. Also, the lubricating oil is conducted by drilled passageway **48** from annular seals **50,50***a* set about the shaft of the rotor and shaft assembly **28** and subsequently drains into the bearing housing assembly.

The rotor and shaft assembly **28** comprises a plurality of juxtapositioned blade mounting rings **52,** each of the rings having a plurality of the blades **32** mounted therein and radially extending away therefrom. Each blade 32 at the head end thereof has a forked extension 54 which is bored through to receive a pin 56. Further, each blade mounting ring has a plurality of boreholes 58 formed therethrough for retaining opposite ends of the blade-retaining pins. Each blade, at the head end thereof, has a laterally extending tang 60 which protrudes into a complementary, interfacing recess 62 provided therefor in an adjacent blade head end. Finally, the forked extensions 54 of adjacent blades have cooperative, arcuate cut-outs 64 formed therein with an elastomeric insert 66 therebetween. The pinning of the forked extensions, and the elastomeric inserts, cooperate to allow the blades to swing through a small arc to accommodate for vibration.

The rotor shaft has a hollow extension 68 about which the rotor blade mounting rings 52 are mounted and, in cross-section, the shaft extension defines a multi-lobed circumference 70. For example, three lobes are defined by three arcs A, B, C of substantially 120°, of common length and radius, but generated from three different, respective loci A', B', C'. By this means, the rotor blade mounting rings are polarized; they are thus located positively on the shaft extension, and are able to transmit the necessary torque.

At the outlet end of the gas compressor is disposed a diffuser shell 72 which is open at both, opposite, ends. One end is in direct open communication with the outlet end of the compression chamber 30, and the end opposite opens directly onto the outlet port 24. One end, the outlet end of this diffuser shell, is retained by a circumferential shoulder 74 formed within the outlet flange and about the outlet port. The diffuser shell outlet end and the circumferential shoulder have a compliant, sealant medium 76 therebetween. Further, the compressor housing has a radially and inwardly extending weldment 78 which abuttingly receives a radial ring 80 formed about and extending from the diffuser shell, said weldment and ring having an O-ring seal 82 therebetween.

Another ring 84 is welded within the outlet end of the housing, intermediate the weldment 78 and the outlet end of the diffuser shell 72, to present a flat-surfaced annulus for slidably supporting the diffuser shell therewithin. Four ribs 86 (only one is shown), equally spaced therebetween about the rotor axis, are fixed at either ends thereof to the annulus of ring 84 and the weldment 78 to provide further support for the diffuser shell therewithin and for the outlet end of the compressor.

The blade mounting rings 52 of the rotor, and the vane mounting rings 38 of the stator as well, are each independently replaceable. The innermost blade mounting ring (i.e., the one nearest the inlet end of the compression chamber) is set up against a circumferential shoulder 88 formed in the outer surface of the rotor shaft extension 68. Successive adjacently-disposed blade mounting rings 52 are set against the innermost one, along the shaft axis. The last or outermost blade mounting ring is secured on the rotor shaft extension by a retainer plate 90 bolted (by means not shown) to the shaft extension.

The vane mounting rings 38 of the stator, similarly are set one against the one adjacent thereto, with the innermost one set against a radial shoulder 92 formed in a cylindrical stator housing 94. The outermost vane mounting ring is secured in position by means of a bi-stepped retainer ring 96. One step 98 of the retainer

ring abuttingly receives the outlet end of the stator housing 94, and the retainer ring is secured to said stator housing thereat. The other step 100 of the retainer ring, being disposed on a face of the ring opposite the first-mentioned step, abuttingly receives the inlet end of the diffuser shell 72. O-ring seals are disposed in both steps to fluid seal the joints formed thereat with the abutting components.

The compliant, sealant medium 76 at the outlet end of the diffuser shell 72, the O-ring seal between and the abutting engagement of the weldment 78 with the diffuser shell ring 80, the slidable support of the diffuser shell on the housing flat-surfaced annulus of ring 84, and the only abutting (i.e., non-fastened) engagement of the inlet end of the diffuser shell 72 with the bi-stepped retainer ring 96, through the O-ring seal, all cooperate to isolate the rotor, and rotor shaft, and the shaft extension thereof as well, from any statically-induced distortion of the housing 12. Only the outlet flange 22, the inlet flanges 16, and the vertical plate 46 are rigidly welded or bolted to the housing 12 and base 14. Therefore, the housing and components rigidly fixed thereto, on the one hand, and the rotating components of the gas compressor, on the other hand, can freely effect minor and relative axial movements therebetween as well as helically (i.e., torsionally) relative to the axis of the gas compressor.

The novel gas compressor comprises means for counteracting axially-directed thrust of the rotor in which the rotor itself, in cooperation with the housing, provides such means. The rotor has a radially extending web 102 formed thereon at the inlet end. The housing vertical plate 46 presents a recess 104 in which the web rotates. An annular, leakage access path 106 formed between a vertical plate shield 108 and the innermost rotor blade admits ambient-pressure gas to one side of the web 102. Another annular, leakage access path formed between the rotor blade mounting ring retainer 90 and an inner cone 110 of the diffuser admits pressured gas to the hollow end 112 of the shaft extension 68. Further, the extension is drilled through, substantially axially, to conduct the leakage pressured gas through a passageway 114 there provided to the vertical plate recess 104. Accordingly, the web 102 encounters compressor inlet pressure on one side thereof — the side from which direction thrust is effected, and outlet gas pressured on the other side thereof — to counteract the thrust. The web 102 engages a labyrinth seal 116, on the circumferential surface thereof, to seal between the disparate pressures.

To effect a foreshortening of stage length, the invention teaches the use of turbine-nozzle-type vanes in the stator. As shown in FIGS. 8 and 9, typical, prior art 50 percent reaction blading requires a stage length of approximately 3.075 inches. Now, with the teaching herein of turbine-nozzle-type stator vanes, as shown in FIGS. 10 and 11, a substantially twenty per cent reduction of stage length (i.e., to approximately 2.55 inches) is realized. It is this teaching which makes it possible to have a great plurality of stages — 10 being shown in FIG. 1, by way of example, in the first embodiment — in a relatively short gas compressor axial dimension. Further, this teaching makes possible the rotary support of the numerous stages of rotor blades and the shaft therefor by means of a single bearing housing at only one end of the shaft.

The gas flow through the rotor blades 32 is oriented in the exit direction. Thus, no guide vanes are required at the entrance to the exit diffuser. Further, the diffuser itself is simplistic and efficient, the same defining a long, conical annulus devoid of obstructive ribs or struts.

The novel compressor, due to the independent replaceability of the vane and blade mounting rings **38** and **52,** renders maintenance and repair easy, and accommodates a facile re-rating of the compressor. Simply by replacing given outermost mounting rings with dummy rings or spacers, or by wholly substituting differently-dimensioned and/or configured vanes and blades — in replacement mounting rings,— the performance of the compressor can be altered.

The alternate compressor embodiment **10'** is quite similar to the first, excepting that the gas inlet and outlet arrangement, and gas compressing "direction," are reversed.

In this embodiment, the conical annulus **118** comprises the gas inlet, and the compression chamber **120** narrows toward the axial end thereof which is opposite the inlet. A side-mounted flange port **122** (only one being shown) comprises the compressed gas outlet.

The thrust counteraction is effected in this embodiment by the admittance of the pressured gas through a passageway **124** formed in the rotor shaft extension for impingement thereof against a pressure plate **126** fixed within the cone **128** of the conical annulus.

While we have described our invention in connection with specific embodiments thereof, it is to be clearly under-stood that this is done only by way of example and not as a limitation to the scope of our invention as set forth in the objects thereof and in the appended claims.

We claim:

1. A gas compressor,

comprising:

a housing defining a compression chamber therewithin;

said housing having means for admitting gas into said chamber and means for discharging compressed gas from said chamber;

radially bladed rotor means for compressing gas within said chamber;

shaft means rotatably mounting said rotor means within said chamber about an axis;

vaned stator means within said chamber replaceably fixed to said housing and cooperative with said rotor means for compressing gas within said chamber;

said chamber having an annular configuration and extending along said axis; wherein

said rotor means extends coaxial with said stator means; and

said shaft means support said rotor means at only one axial end of said rotor means, providing cantilevered mounting of said rotor means within said chamber; and further including

means disposed between said housing and at least one of said rotor, stator, and shaft means for isolating said rotor and shaft means from statically-induced distortions of said housing; wherein

said rotor means includes means cooperative with said housing for counteracting axially-directed thrust of said rotor means; and

said thrust counteracting means comprises a web, having first and second oppositely disposed bearing surfaces, formed on one axial end of said rotor means, and conduit means, formed in said rotor means, communicating said discharge means and compressed gas issuing therethrough with said first bearing surface; wherein

said web is disposed in a recess formed in said housing; and further comprises

a passageway formed in said housing which communicates said second bearing surface with the atmosphere and means sealing between said conduit means and said passageway.

2. A gas compressor, according to claim **1,** wherein:

said discharging means includes a diffuser having an annular configuration extending coaxial with said given axis and a uniformly varying and unobstructed cross-section from one axial end thereof to the other.

3. A gas compressor, according to claim **1,** wherein:

said web extends radially from said one axial end of said rotor.

4. A gas compressor, according to claim **1,** wherein:

said stator means comprises a cylindrical member enveloping said chamber;

said member having an inwardly-directed, radial shoulder formed on one end thereof, and a uniform-diameter, cylindrical, mounting surface extending from said shoulder to the end of said member which is opposite said one end;

a plurality of vane mounting rings disposed in juxtaposition upon and about said mounting surface, a first one of said mounting rings being set against said radial shoulder, others thereof being set out from said first one, successively, along said axis, toward said opposite end;

pluralities of vanes;

means mounting a plurality of vanes to each of said mounting rings;

said cylindrical member having an annular recess formed therein at said opposite end;

a retainer ring fixed in said recess, and to said member, for securing said juxtapositioned vane mounting rings on said member; and

fasteners, in penetration of said member and threadably secured in said rings, cooperative with said retainer ring to secure said mounting rings onto said member.

5. A gas compressor, according to claim **4,** wherein:

all vanes in said plurality of vanes are of uniform length; and

each vane mounting ring of said plurality thereof is of discrete cross-sectional dimension.

6. A gas compressor, according to claim **5,** wherein:

said vane mounting rings, and the discrete cross-sectional dimensions thereof, cooperate with said rotor means to define said chamber with a varying cross-section from one axial end thereof to the other.

7. A gas compressor, according to claim **4,** wherein:

each of said vane mounting rings is independently replaceable from said cylindrical member.

8. A gas compressor, according to claim **4,** wherein:

vanes of each plurality thereof have ends thereof fixed in their respective vane mounting ring; and

said stator means further comprises means securing said vane ends in said respective vane mounting rings, and means for resiliently enveloping said vane ends and damping said vanes against vibration.

9. A gas compressor, according to claim 4, wherein: said vanes have a cross-sectional configuration which conforms with a turbine nozzle cross-sectional configuration, comprising a thick, bulbous inlet section, a markedly arcuate mean camber line, and a chord line, a greater portion of which lies external of said vane cross-section.

10. A gas compressor, according to claim 1, wherein: said rotor means comprises pluralities of rotor blades, said stator means comprises pluralities of stator blades, said rotor and stator blades being cooperative to define a plurality of successive compressing stages along said axis, from an inlet end to an outlet end of said compression chamber; and

each of said stages encompasses an axial length of not more than 2.55 inches.

11. A gas compressor, according to claim 10, wherein

said discharging means comprises a diffuser having an inlet and an outlet; and

said inlet of said diffuser opens directly, in immediate adjacency thereto, onto the outermost and last compressing stage.

12. A gas compressor, comprising:

a housing defining a compression chamber therewithin;

said housing having means for admitting gas into said chamber and means for discharging compressed gas from said chamber;

radially bladed rotor means for compressing, gas within said chamber;

shaft means rotatably mounting said rotor means within said chamber about an axis;

vaned stator means within said chamber replaceably fixed to said housing and cooperative with said rotor means for compressing gas within said chamber;

said chamber having an annular configuration and extending along said axis; wherein

said rotor means extends coaxial with said stator means; and

said shaft means support said rotor means at only one axial end of said rotor means, providing cantilevered mounting of said rotor means within said chamber; and further including

means disposed between said housing and at least one of said rotor, stator, and shaft means for isolating said rotor and shaft means from statically-induced distortions of said housing, wherein

said rotor means comprises a shaft extension coupled to said shaft means;

said shaft extension comprising a cylindrical member which, in cross-section, defines a plural-lobe periphery, all lobes of said periphery being of common curvature and length, and each curvature of each lobe defining an arc generated from a radial locus distinct from the radial loci of the other arcs of the other lobes.

13. A gas compressor, according to claim 12, wherein:

said shaft extension, in cross-section, defines a three-lobe periphery; and

said rotor means further comprises a plurality of blade mounting rings disposed in juxtaposition upon and about said periphery; pluralities of blades; and means mounting a plurality of blades to each of said blade mounting rings.

14. A gas compressor, according to claim 15, wherein:

each of said blades has a mounting head on one end thereof which defines a bifurcation;

said mounting heads and said blade mounting rings have boreholes formed therethrough; and

said mounting means comprises pins in penetration of said boreholes for securing said blades to said blade mounting rings and for accommodating slight pivotal movement of said blades about said pins.

15. A gas compressor, according to claim 14, wherein:

said mounting heads each have a laterally extending tang formed on one side thereof and a tang-receiving recess formed in the side thereof opposite said one side, for effecting a contacting inter-engagement of each mounting head with a mounting head adjacent thereto; and

said mounting heads each have arcuate cut-outs formed on said one and said opposite sides; and further including

elastomeric inserts disposed in said cut-outs, between each of said mounting heads, for cooperation with said pins to provide for vibration-damping of said blades.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,773,430 Dated Nov. 20, 1973

Inventor(s) Fred Canova, et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the first page of the patent, the INID Code [75] information should read: --Fred Canova, Wellsville, N.Y.; Leroy M. Krouse, Hanns Hornschuch, and Paul Hermann, Easton, Pa; Joseph A. Dopkin, Hopewell, N.J.--.

Signed and sealed this 9th day of April 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents