CENTRIFUGAL GASEOUS MEDIUM COMPRESSOR

Filed Nov. 30, 1966 Sheet 1 of 8

FIG. 1

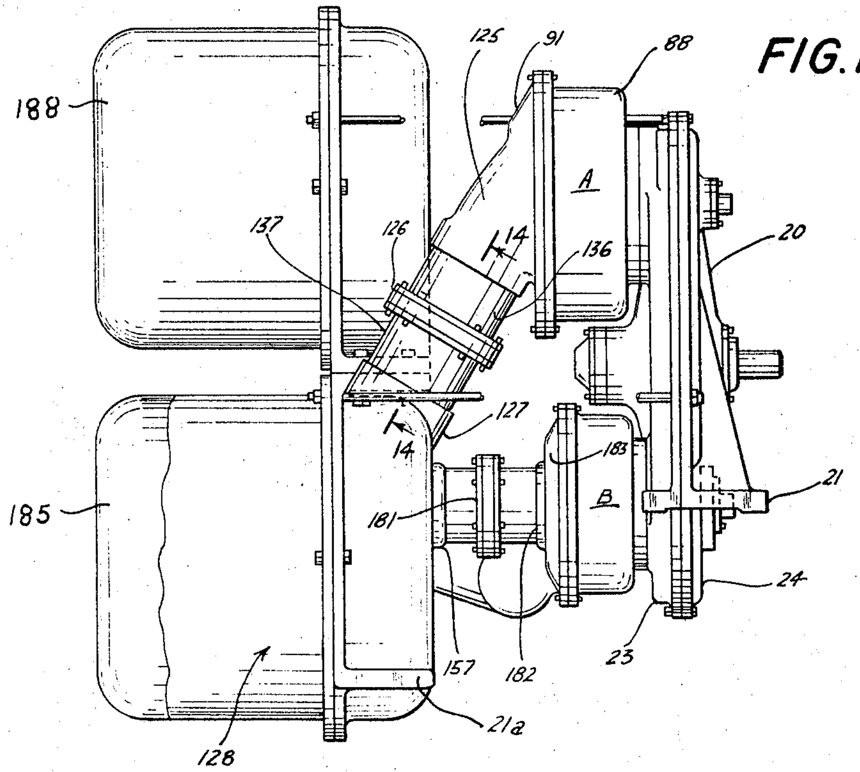

FIG. 2

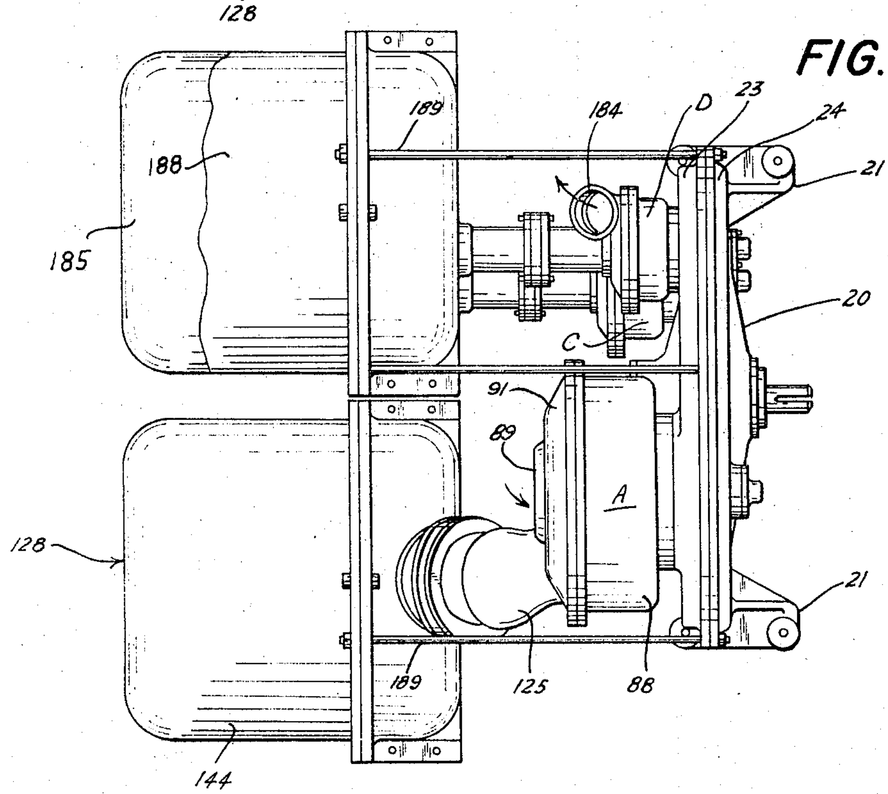

FIG. 3

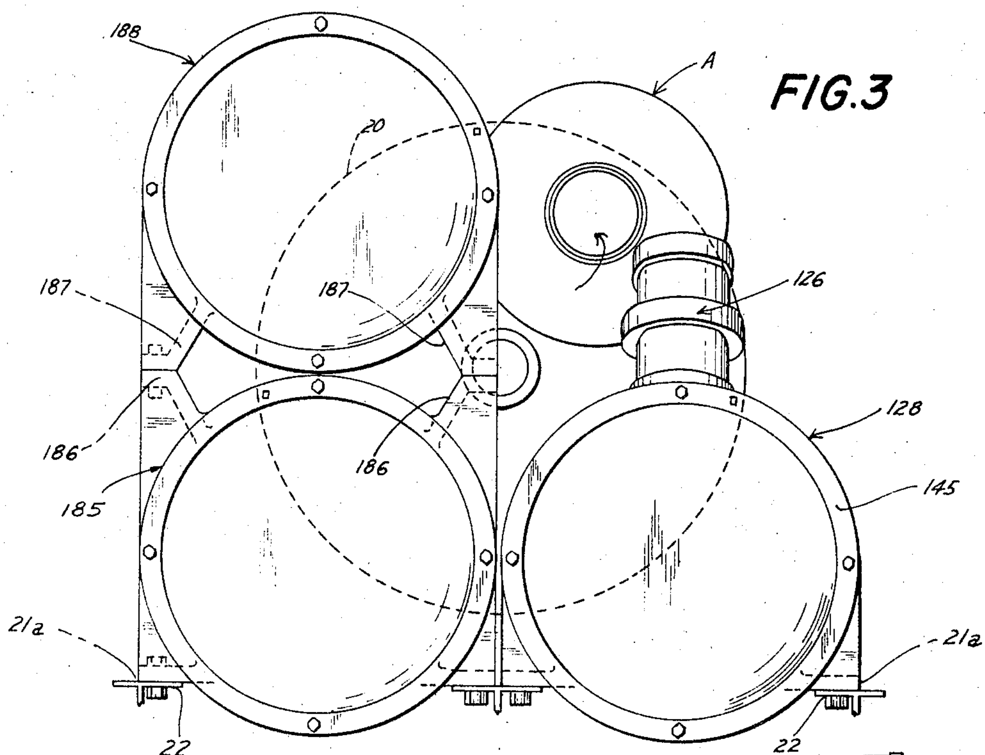

FIG. 12

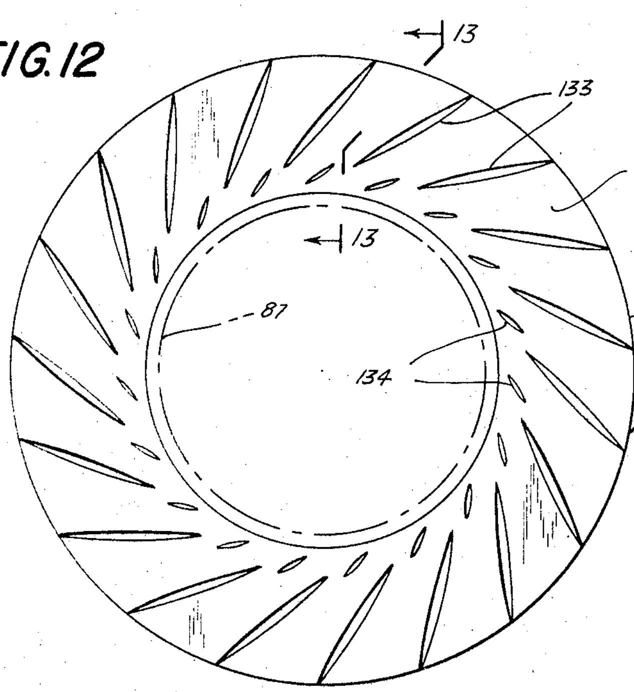

FIG. 13

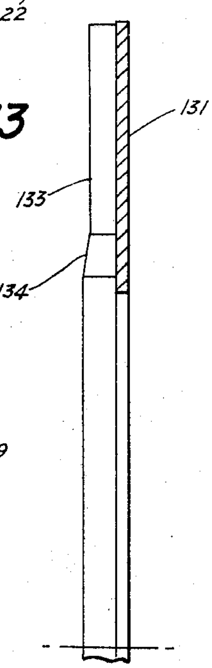

FIG. 4

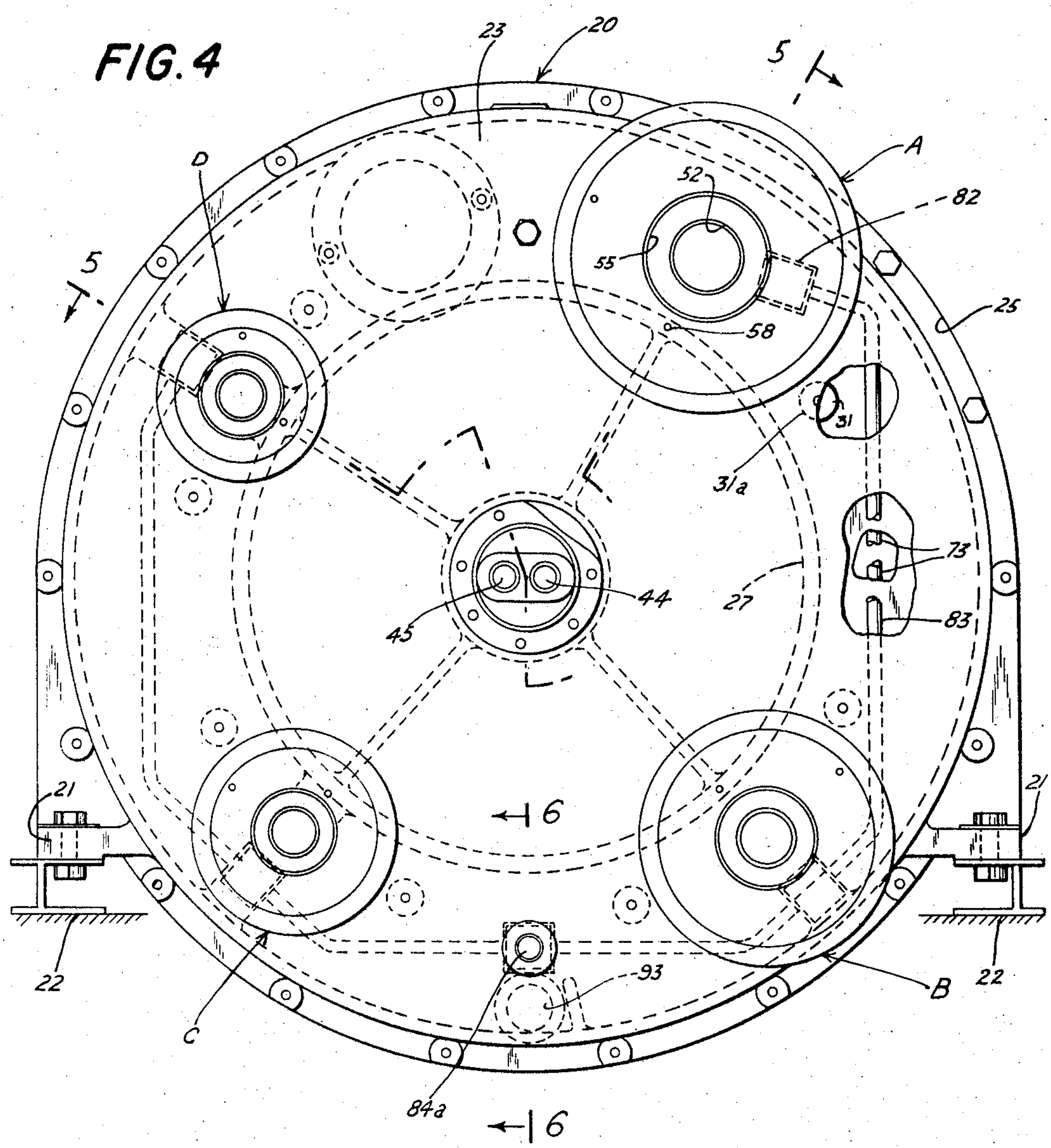
23
20
5
A
52
82
55
25
58
D
5
31
31a
73
44
27
45
83
6
21
21
22
22
93
B
C
84a
6

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FIG. 5

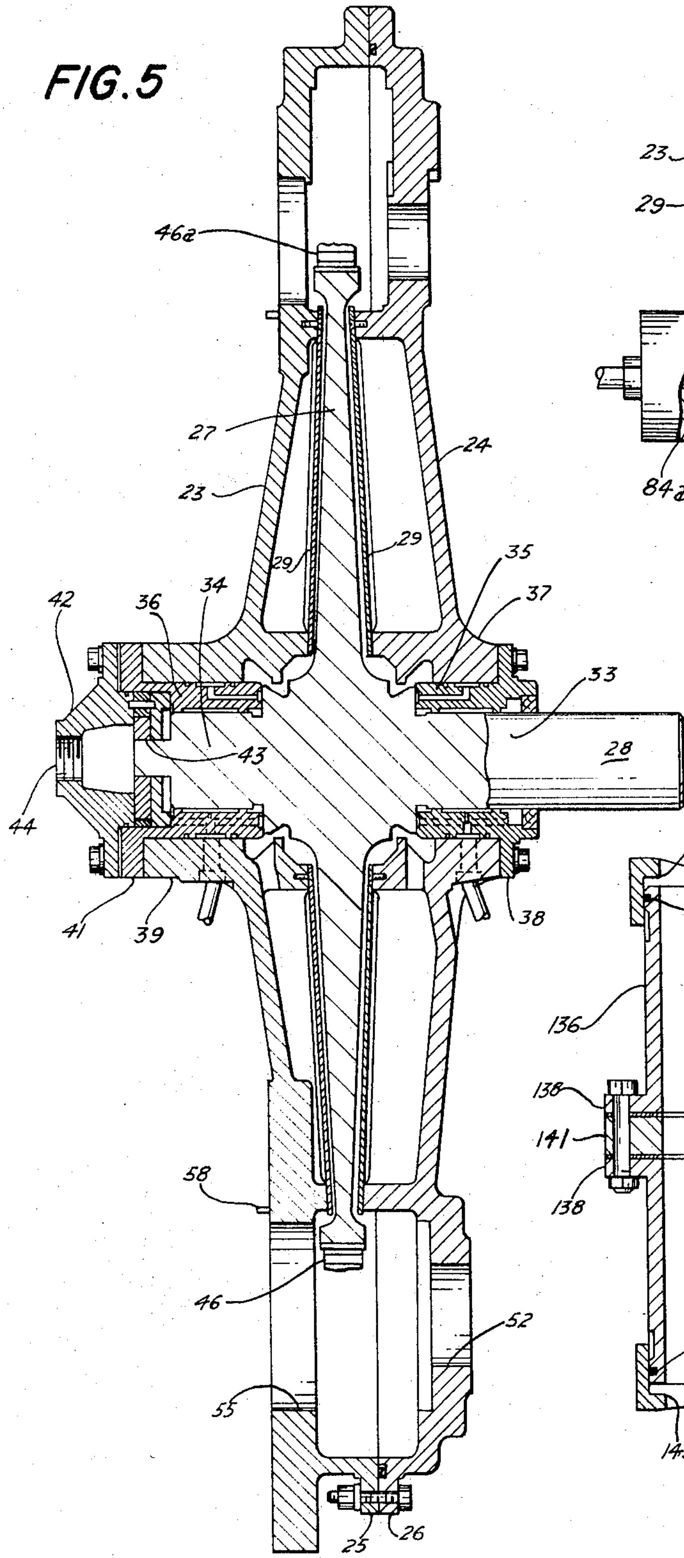


FIG. 6

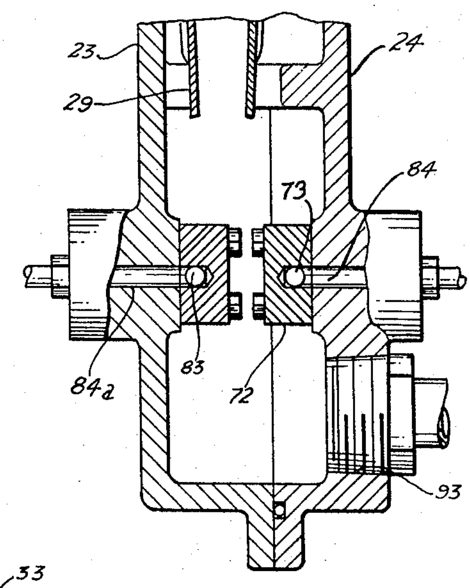


FIG. 14

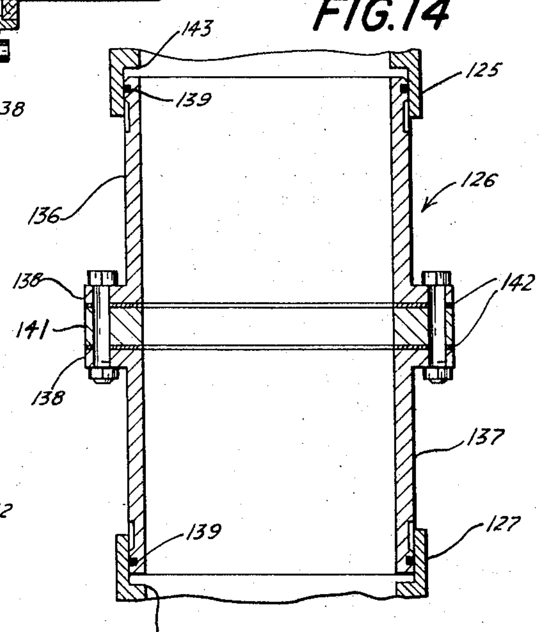
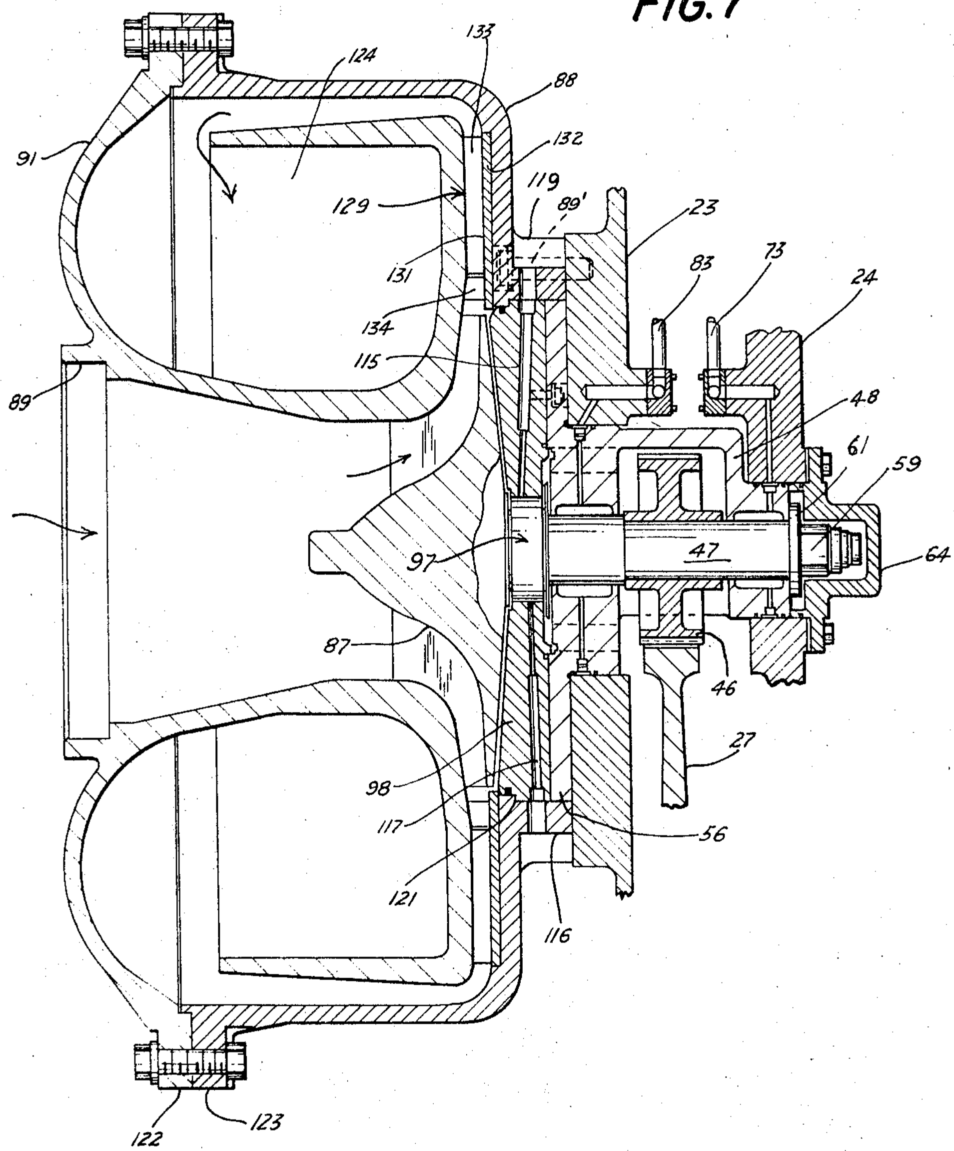


FIG. 7


133
124
88
91
132
129
119
89'
23
131
83
73
24
134
115
89
48
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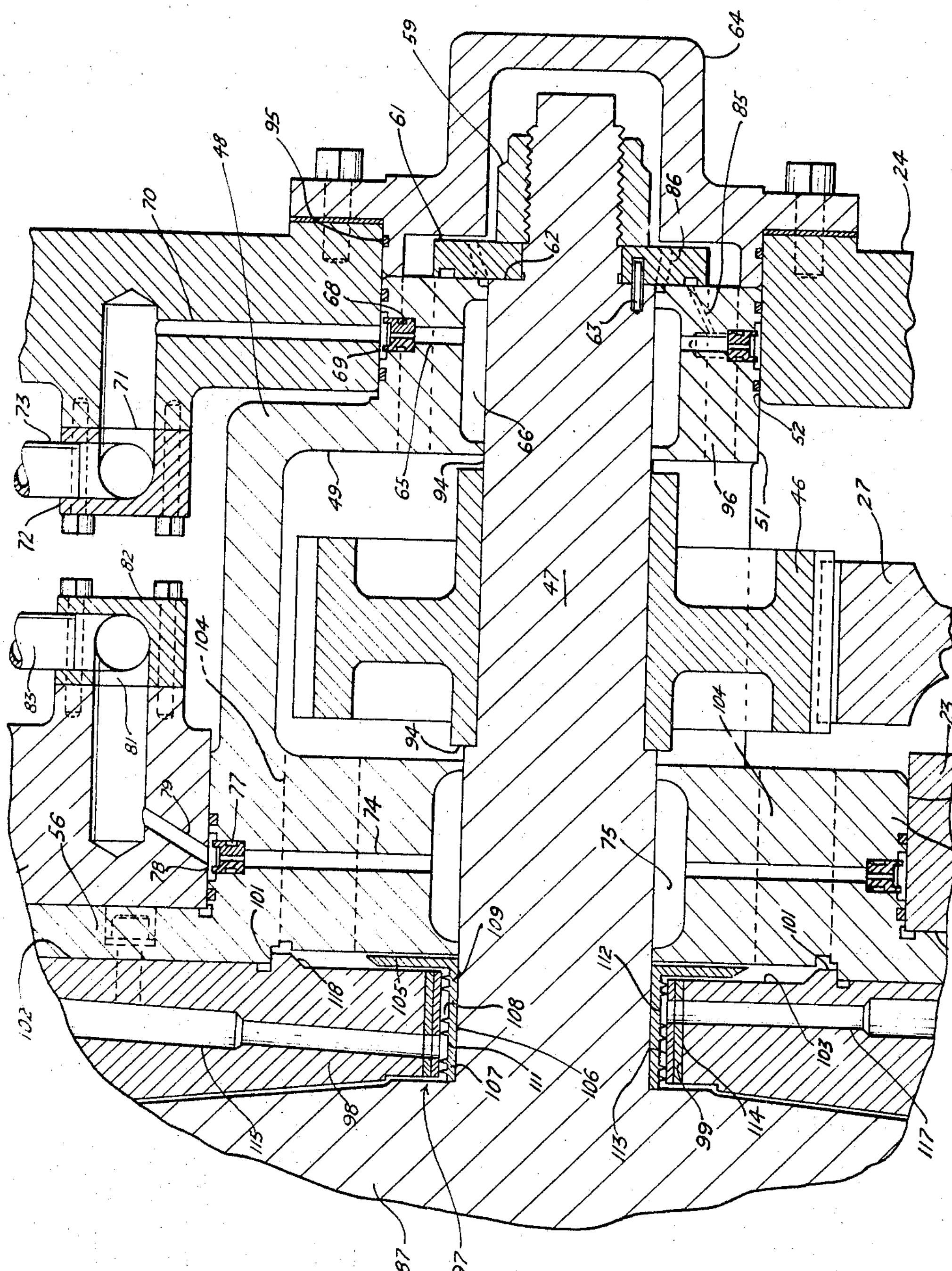
59
97
47
64
87
46
27
98
117
56
121
116
122
123



59
64
61
95
85
48
86
24
70
62
68
63
69
71
66
52
73
65
94
96
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51
46
27
72
47
82
104
83
81
94
104
23
77
74
75
55
79
53
78
56
101
101
109
112
118
105
108
103
102
107
111
106
115
98
97
113
99
114
117
87

FIG. 8

FIG. 9

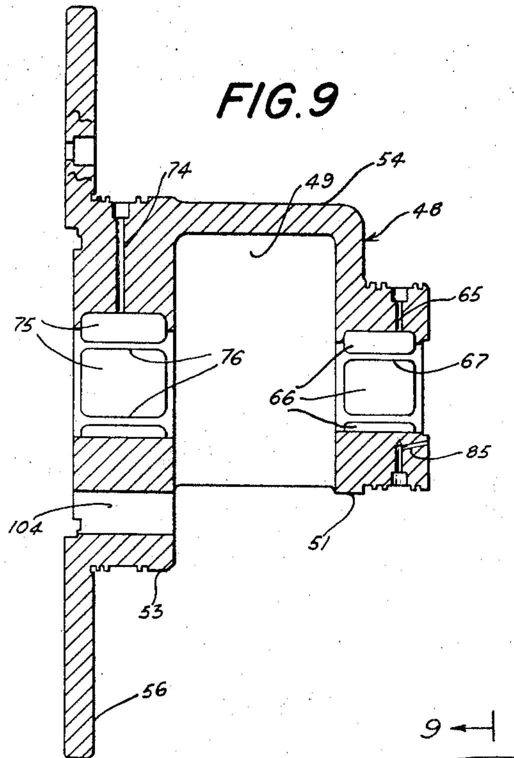


FIG. 10

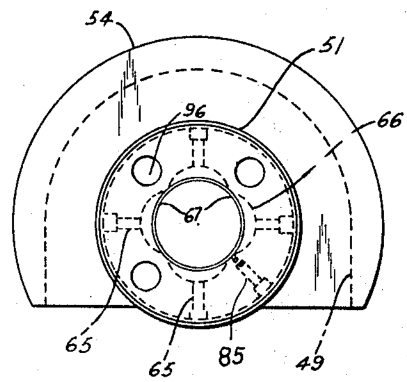
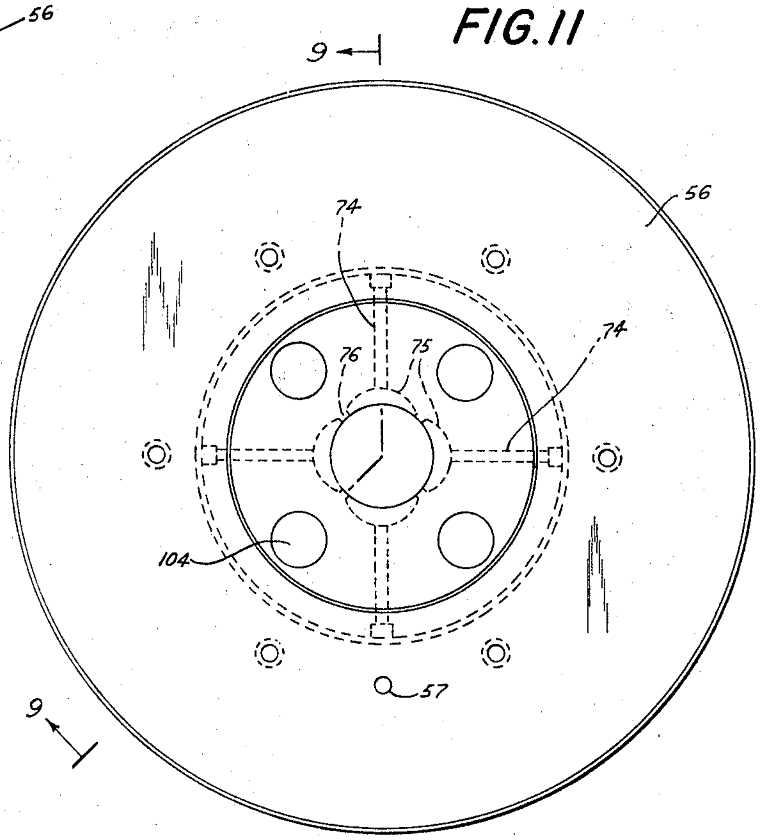


FIG. 11



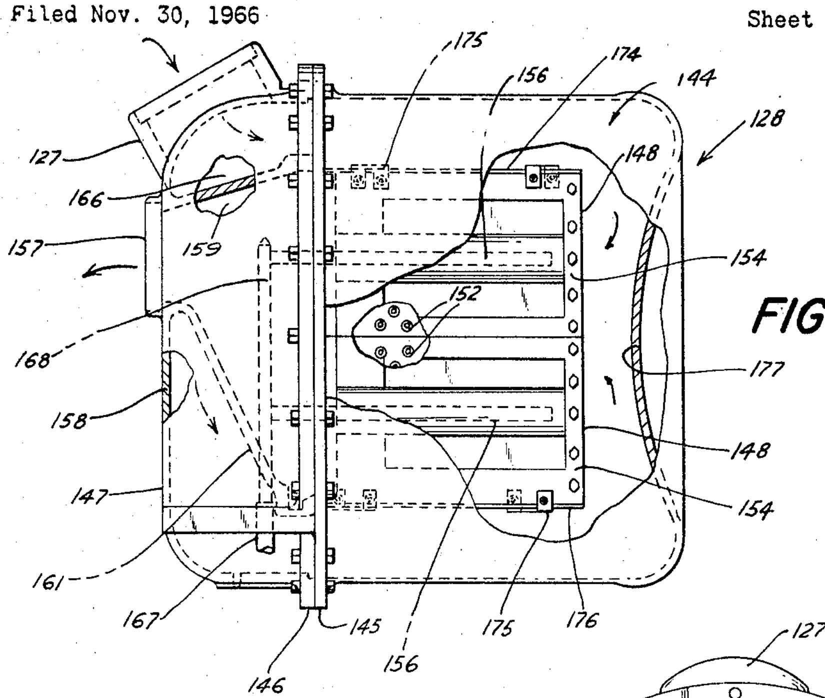


FIG. 15

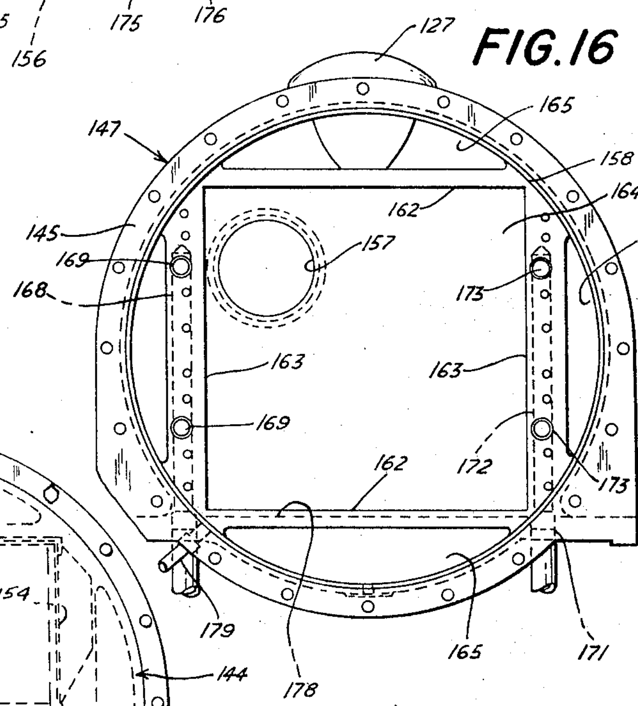


FIG. 16

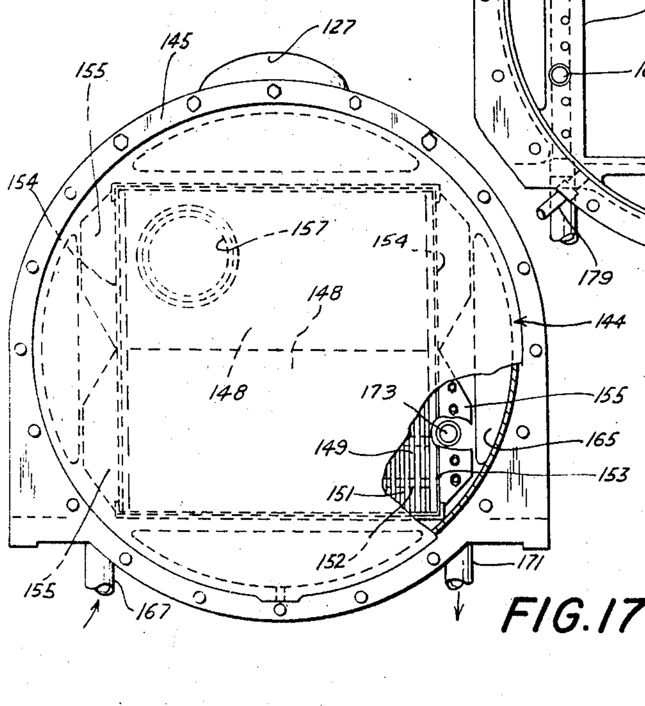


FIG. 17

United States Patent Office

3,424,372

Patented Jan. 28, 1969

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3,424,372

CENTRIFUGAL GASEOUS MEDIUM COMPRESSOR

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Filed Nov. 30, 1966, Ser. No. 598,082

U.S. Cl. 230—127 17 Claims

Int. Cl. F04d 17/08, 17/12, 29/58

ABSTRACT OF THE DISCLOSURE

A compressor of the centrifugal type having a multiple number of compressor impeller assembly units, each directly driven by a common bull gear. It is suitable for the compression of air as well as other gases. The compressor units which differ from one another in size are mounted in an orderly arrangement about one side of a common gear casing which houses the bull gear; and they are interconnected with one another by means of heat exchange units. Each compressor unit provides a separate stage of compression for the air drawn into it. The air drawn into each stage is efficiently compressed by its impeller through an individual diffuser unit and scroll into a separate one of the heat exchange units wherein it is cooled and freed of moisture before it is caused to be drawn into the next succeeding compressor unit for a further stage of compression. The air is finally discharged in a highly compressed condition from the final compressor unit.

This invention relates to the art of centrifugal gaseous medium compressors.

Multiple stage centrifugal compressors are known from United States Patent 3,001,692 to Schierl and the Swiss Patent 102,821 to Brown. These devices, however, do not obtain the advantages provided by the subject invention.

The nature of the compressor impeller assembly units is a principal feature of the apparatus. Each unit is a complete assembly or cartridge which is individually readily attachable and removable as such relative to the common gear casing and to the bull gear without disturbing any of the other units. The unit is provided with an advantageous bearing and with a sealing arrangement whereby an impeller shaft of the unit is borne in the casing with a dual bearing support as it rotates and whereby the bearing fluid, and the air stream being actuated by the impeller, are prevented from contaminating one another.

Associated with each compressor unit is an improved diffuser unit having a group of turning vanes which cooperates with a group of diffusing vanes, whereby the air stream discharged from the impeller is slowed or guided to flow efficiently through a scroll.

A separate improved heat exchange unit or intercooler interconnects each compressor unit or stage with the next. Each unit may be readily assembled to or detached as a unit from the apparatus independently of the other units.

The several compressor impeller assembly units as well as the heat exchange units and interconnecting piping are all located and supported in an advantageous manner to one side of the common gear casing, whereby the load upon the casing and upon the general support of the apparatus is advantageously distributed. The piping connections between the heat exchange units and the

2

impeller assembly units are such that the approach for flow to the impellers is straight without bends.

Further, the heat exchange units are coupled to the scrolls associated with the compressor units by floating piping having a minimum of parts which may be readily assembled or disassembled without disturbing the related connected components.

As a consequence of the foregoing structure and the component members thereof an efficient and practical improved centrifugal air compressor is provided which represents a decided advance in this art.

In the accompanying drawings:

FIG. 1 is a side elevational view of a four stage centrifugal air compressor illustrating the invention;

FIG. 2 is a top plan view of FIG. 1;

FIG. 3 is a left end elevation of FIG. 1;

FIG. 4 is an elevational view of the rear face of the gear casing, the compressor units being removed for clarity of illustration;

FIG. 5 is a section on line **5—5** of FIG. 4;

FIG. 6 is a section on line **6—6** of FIG. 4;

FIG. 7 is a sectional view of a compressor impeller assembly unit in association with the related scroll and the gear casing;

FIG. 8 is an enlarged section of the unit shown in FIG. 7;

FIG. 9 is a detail in section of the bearing block taken on line **9—9** of FIG. 11;

FIG. 10 is a right end elevational view of FIG. 9;

FIG. 11 is a left end elevational view of FIG. 9;

FIG. 12 is a detail in elevation of the diffuser unit;

FIG. 13 is an enlarged sectional view on line **13—13** of FIG. 12;

FIG. 14 is an enlarged section on line **14—14** of FIG. 1;

FIG. 15 is a detail in side elevation of a heat exchange unit;

FIG. 16 is a rear elevational detail of the header of the heat exchange unit of FIG. 15; and

FIG. 17 is a rear elevational view of the heat exchange unit of FIG. 15.

The four-stage air compressor illustrated in the drawings includes a gear casing **20** serving as a common and direct support for the several stages, generally indicated in FIGS. 1 and 2 by the letters A, B, C and D and having correspondingly designated locations in FIG. 4. The casing has at opposite peripheral areas a pair of foot flanges **21** each adapted to be bolted to a supporting base, such as a steel beam **22**. The casing **20** (FIGS. 1, 4–6) is formed of a pair of opposed circular dished plates **23** and **24**. The rear plate **23** has a peripheral bordering flange **25** which is rigidly bolted fluid-tight to a complementary flange **26** of the front plate **24**. A large bull gear **27** is carried by a shaft **28** for rotation in the narrow chamber defined between the walls of the plates. A close clearance is maintained between the side areas of the gear and a pair of opposed circular baffle plates **29**, one being mounted to each of the internal walls of the casing to reduce windage. A clearance of approximately one-eighth of an inch has been found conducive to good results.

The casing plates are strengthened by means of a ring of bosses **31** and **31**_a_ formed on the interior of the opposed casing plates in the area beyond the periphery of the bull gear; the bosses are bolted in face-to-face abutment. End portions **33** and **34** of the shaft are rotatably supported in a pair of suitable bearings such as hydrostatic oil bearings **35** and **36**. Bearing **35** is fitted in the opening of an axially extending hub **37** of the front plate **24** and is retained in position by means of an external flange **38** bolted to the hub. The shaft end **33** extends extends externally of bearing **35**; and it is adapted to be coupled to a suitable prime mover or motor, preferably a constant speed electric motor (not shown). The other bearing **36** is fitted in the opening of an axially extending hub **39** of the rear plate **23**, and has an external flange **41** abutting the hub. A lube pump manifold **42** overlies flange **41**; and the manifold and flange are bolted fast to the hub. A lube gear pump **43** carried by the shaft draws fluid lubricant through an inlet **44** of the manifold, and pumps it under pressure through an outlet **45** of the manifold to circulate it through a lube system, later to be described herein, to the various components of the apparatus. The bull gear **27** directly drivingly engages a separate pinion gear associated with each of the compressor stages A, B, C and D. The pinions **46** and **46***a* of stages A and D are shown in part in FIG. 5. It is understood that the number of compressor stages to be associated with the bull gear may vary.

Since the several stages are typical of one another or are of similar construction, except for size, only one of the stages is described in detail herein (FIGS. 7–11). The pinion **46** is carried by an impeller shaft **47** of the first compressor stage A. The impeller shaft is supported in a bearing means, here illustrated as a cylindrical stationary hydrostatic bearing block **48**, for rotation on an axis parallel to that of the bull gear. The bearing block is bifurcated in its periphery **54** between its ends to provide an annular bifurcation or space **49** in which the pinion **46** is freely rotatable. The pinion projects radially out of the bifurcation sufficiently to engage the bull gear. At one side of the bifurcation the bearing block has a broad bearing end portion **51** of reduced diameter having a slide fit in an opening **52** of the front casing plate **24**. At the opposite side of the bifurcation the bearing block has a second broad bearing portion **53** of greater diameter than the diameters of the bifurcated portion and of the reduced bearing portion **51**. This large diameter bearing **53** has a slide fit in an opening **55** of the rear casing plate **23**. The bearing block terminates adjacent the large bearing **53** in a radially extending circular flange **56**, the inner face of which abuts upon the exterior face of the rear casing plate **23** and accordingly determines the extent to which the bearing block may be inserted into the casing openings **52** and **55**. Flange **56** has a guide pin hole **57** in which a guide pin **58** projecting from the rear casing plate is received as a means of determining the proper angular position of the bearing block relative to the gear casing. The guide pin in cooperation with the guide pin hole locates the bearing block so that the open end of its bifurcation **49** overlies or spans the periphery of the bull gear **27** and so that the pinion **46** engages with the latter. The guide pin also restrains relative rotation between the bearing block and the gear casing. A nut **59** screwed upon a reduced terminal end of the impeller shaft holds a hydrostatic thrust collar **61** against a shoulder **62** of the impeller shaft; and a pin **63** prevents rotation of the collar relative to the shaft. The collar is positioned opposite the end face of the stationary bearing block. When the bearing block is seated in the openings **52** and **55** of the gear casing, the nut protrudes externally of the front plate **24**. A crown cap **64** bolted to plate **24** protectively covers over the nut and thrust bearing.

The small bearing **51** of the bearing block has a plurality of circumferentially equally spaced radial lube holes **65**, here four. Each hole communicates at its inner end with a separate internal lube cavity or pocket **66** of the bearing block overlying the impeller shaft. The several cavities are separated from one another by relatively narrow lands **67**. An orifice **68** in each lube hole communicates with a common lube distribution channel or annulus **69** about the periphery of the bearing. Channel **69** registers with a lube passage **70** in the front casing plate **24**. This passage in turn communicates through the interior of the plate with a port **71** in a supporting clamp **72** of one branch, generally indicated at **73** (FIGS. 4, 8) of a high pressure tubular lube assembly system. This branch line **73** is mounted about the interior wall of the front plate **24**. The large bearing **53** of the bearing block has a similar group of radial lube holes **74**, each similarly communicating at its inner end with a separate internal lube cavity **75** overlying the impeller shaft, the cavities being separated from one another by relatively narrow lands **76**. Holes **74** are also fitted with orifices **77** having communication with a common peripheral lube distribution channel **78** registering with a lube passage **79** in the rear casing plate **23**. Passage **79** communicates through the interior of the plate with a port **81** in a supporting clamp **82** of a second branch line **83** of the lube system. Branch line **83** is mounted about the interior surface of the rear plate **23**. Each of the branch lube lines terminates in a separate feed port **84** or **84***a*, each having a pipe connection with the outlet **45** of the pump manifold. High pressure oil pumped into the branch lube lines **73** and **83** flows through the several lube holes **65** and **74** of the bearings to simultaneously fill the several related cavities **66** and **75** about the impeller shaft with pressurized fluid, causing the shaft to be hydraulically borne for rotation. At no time during rotation of the shaft is there any metal contact between the bearing block and the impeller shaft, since a film of oil at all times separates the shaft from the bearing block. A passage **85** in the small bearing **51** bleeds oil from the annulus **69** to the thrust collar **61** to provide an oil film between the bearing block and the thrust collar. Ports **86** extending through the thrust collar permit free flow of oil about the latter.

An air compressor impeller **87** of the air inducing blade type is formed integral with the other end of the impeller shaft. The impeller is disposed externally of the gear casing plate **23**. It operates in an individual impeller case **88** mounted by means of a ring of bolts **89′** to the exterior of the gear casing plate **23**. Air sucked in by the impeller through an inlet pipe **89** of a scroll **91** covering over the impeller case is compressively discharged through the periphery or exit end of the impeller into the volute **124** of the scroll.

Since the oil hydrostatically bearing the impeller shaft is under high pressure, some of it will bleed from the several cavities **66** and **75** through the normal slight clearance or looseness existing between the lands of the bearing block and the shaft. Some of this oil will bleed along the shaft into the bifurcation **49**. This bled oil will eventually drip down about the bull gear **27** and over the baffle plates **29** to the bottom of the gear casing from where it will be drained off to a sump through an outlet **93**. Some of the oil bleeding along the impeller shaft into the clearances **94** adjacent the pinion **46** will be thrown by the shaft to the curved bottom of the bifurcation and splashed about to lubricate the pinion. Some of the oil will also bled from the bearing block along the shaft around the thrust collar and nut **59**. An O-ring **95** between the end cap and the front casing plate will seal against leakage to the outside of the casing. Excess fluid collecting in the end cap will drain through axial ports **96** in the small bearing into the bifurcation.

Some of the oil fed to the bearing block **48** will also bleed around the shaft from the large bearing toward the impeller end of the shaft. An advantageous sealing arrangement, generally indicated at **97**, is provided about the impeller shaft between the back of the impeller and the bearing block to prevent this oil from entering the impeller case and contaminating the air being compressed through the scroll. It also prevents the highly compressed air in the impeller case from leaking around the shaft and possibly adversely affecting the condition of the oil in the bearing block.

The sealing arrangement **97** includes a thick circular baffle seal plate **98** having an axial opening **99** through which the impeller shaft extends. The baffle seal plate has a back face divided by an annular rib **101** into inner and outer annular surface areas. The outer area **102** serves as a mount, and is bolted flush upon a corresponding end face area of the flange **56** of the bearing block; and the inner area defines with an opposed slightly recessed central face area of the bearing block a narrow annular radial cavity **103** surrounding the impeller shaft. A group of axially extending drain holes **104** in the bearing block communicates this cavity with the bifurcation **49**. Extending radially partway into this cavity while mantaining a slight clearance between the opposed walls of the cavity is a collar or oil slinger **105** defining one end of an anular seal **106**. This seal is fitted fast upon the impeller shaft immediately to the back of the impeller. The seal has around its surface a plurality of parallel knife edges, here, arranged in three groups, designated **107**, **108** and **109**. The end groups **107** and **109** are spaced from the middle group **108** by means of peripheral channels or annuli **111** and **112**. A liner **113**, formed of abradable material having slight resilience of yieldability, such as Teflon plastic, fibre metal or material known by the trademark Feltmetal, is bonded to a tubular element **114** fitted fast in the axial opening **99** of the baffle seal plate. The liner bears upon the several knife edges; and is subject to being slightly grooved by the knife edges as the impeller shaft is rotated. Channel **111** of the seal registers with a radial vent passage **115** extending upwardly in order through the liner, the tubular element, the baffle seal plate and a hub collar **116** of the impeller case. The channel **112** registers with a second radial vent passage **117** extending downwardly in order through the liner, tubular element, the baffle seal plate and the hub collar **116**.

The effect of the sealing arrangement **97** is to cause any high pressure air that might leak from the impeller case around the slight clearance normally existing at the back of the impeller through the tortuous passage provided by the knife edges and liner to the interseal annulus **111** to vent through passage **115**; and to also cause any vapors that might escape from the bearing block through the tortuous passage provided by the seal collar and knife edges and liner to the interseal annulus **112** to vent through the vent passage **117**. Oil bleeding from the bearing block to the radial cavity **103** will be centrifugally thrown or slung by the seal collar **105** into the drain holes **104** from where it will drain through the bearing block to the bifurcation. A bevel **118** at the upper end of the cavity aids in deflecting into the drain holes **104** much of the oil tossed from the collar **105**.

It is apparent that the several components surmounted upon the impeller shaft as above described define a cartridge or a compressor impeller assembly unit held together as such by means of the impeller **87** at one end of the impeller shaft and by means of the nut **59** at the other end. In making up the compressor assembly unit the baffle seal plate **98** is first fitted with the tubular element **114** containing the slightly resilient liner **113**. The annular seal **106** is then inserted in the liner. In the later action, the liner yieldably expands to receive the seal and then retracts to press upon the knife edges of the inserted seal. Next, the bearing block **48** with the pinion **46** located in its bifurcation are assembled upon the shaft; and the flange **56** of the bearing block is then bolted to the baffle seal plate. The thrust collar **61** is next fitted onto the shaft. The entire assembly is then finally made secure upon the shaft between the impeller at on end and the nut **59** which is finally screwed into position on the opposite end of the shaft. This assembled unit defines a cartridge which may be packaged as such for ready assembly or replacement in the gear casing. This construction is of considerable advantage in the art of centrifugal compressors in that it enables the assembly to be slidably mounted in, or removed from, the casing as a cartridge or unit. It obviously saves considerable time in assembly, replacement and repair operations. After the impeller assembly unit has been properly positioned in the gear casing, it will be retained in its proper position against endwise movement by means of the hub collar **116** of the subsequently mounted impeller case **88**. The hub collar has a slidable sleeve fit over the peripheries of the baffle seal plate **98** and the flange **56** of the bearing block. Radial flange means **119** about the end of the hub collar is bolted by means of a ring of bolts **89'** to the exterior of the rear casing plate **24**. Cooperating shoulder means **121** of the hub collar and of the baffle seal plate restrain the compressor impeller assembly unit against axial movement away from the gear case. The axial opening of the hub collar **116** is of greater diameter than that of the impeller, so that during assembly of the impeller case to the gear casing the hub collar may be passed freely over the impeller and sleeved upon the baffle seal and flange plates **98** and **56**.

The scroll cover **91** covering over the impeller case has an annular end flange **122** bolted to a complementary flange **123** of the impeller case. The scroll cover has a short axial inlet suction pipe **89** through which air is drawn by the rotating impeller into the impeller case; and it has an internal volute **124** ending in a short discharge pipe **125** (FIGS. 1, 2) through which the air is compressively discharged by the impeller. The discharge pipe is connected by means of a floating pipe coupling **126** (FIGS. 1, 14) to a short inlet pipe **127** of an intercooler or heat exchange unit **128**. The intercooler serves to cool and dry the heated air discharged from the impeller preparatory to permitting it to flow to a succeeding stage for further compression.

A diffuser unit **129** (FIGS. 7, 12, 13) is arranged about the periphery or exit end of the impeller **87** to diffuse the air stream leaving the impeller so as to cause it to flow smoothly and with reduced velocity through the scroll to be discharged into the related intercooler unit. Here, the diffuser comprises an annular flat plate **131** seated in a complementary recess **132** of the inner back wall of the impeller case. The plate has formed upon its open face a plurality of vanes in the form of long and short air-foils **133**, **134**. These lie in the narrow radial annular passage located about the peripheral exit end of the impeller and defined between the opposing walls of the scroll and the impeller case. The back wall of the scroll bears upon the outer surfaces of the vanes so as to restrain the diffuser in its seated condition. The vanes are arranged in two concentric rows; and the vanes in each row are spaced circumferentially similarly apart, whereby a plurality of passages or throats **135** are provided across the face of the diffuser plate for the air stream leaving the impeller. The short vanes **134** occupying the inner row are disposed at an angle relative to the peripheral exit end of the impeller; and they have their leading edges in close proximity to the exit end of the impeller. The short vanes cause very little diffusion of the air leaving the impeller. They serve primarily to straighten out or turn the air stream toward the longer vanes so as to cause it to follow the long vanes.

The long vanes serve the usual function of diffusing the air stream leaving the impeller and providing a favorable passage for it into the scroll; whereas the short vanes have negligible diffusing effect and serve primarily to guide or bend the air stream favorably toward the diffuser vanes and the passages between them. The longer vanes are arranged at substantially the same angle as that of the shorter vanes, whereby the angle of air stream flow over the short and long vanes is substantially constant and favorable diffusion results are obtained. The outer row of long vanes are offset angularly a little from the inner row; so that the flow over the second row of vanes starts smoothly with substantially no attendant wake. The effect of the longer vanes is to substantially reduce the velocity of the air stream leaving the impeller and to convert it into pressure. Here, the long and short vanes are shown arranged at about 30° to the periphery of the impeller.

The floating coupling **126** (FIGS. 1, 14) is of decided advantage in the centrifugal compressor art. It enables the scroll cover **91** of the impeller case, and the related intercooler unit **128** to be coupled to one another or separately disassembled without disturbing the position or mounting of the other. It also has other apparent inherent advantages. The coupling includes a pair of similar pipe sections **136** and **137**, each terminating in a radial flange **138** at one end; and each having an opposite free end provided with a peripheral groove in which is seated and O-ring seal **139**. A pipe spacer **141** is disposed between the end flanges. The spacer, together with the pipe sections and intermediate sealing gaskets **142** are movably bolted to one another by means of a ring of bolts. The free end of pipe section **136** has a slide fit in the short discharge pipe **125** of the scroll cover; and it is limited in the extent to which it may be inserted by means of an internal shoulder **143** of the discharge pipe. The O-ring **139** seals the inserted pipe section fluid tight. The free end of the other pipe section **137** has a similar association with the short inlet pipe **127** of the intercooler unit. The overall length of the assembled coupling is a little shorter than the distance between the internal shoulders **143** of the discharge and inlet pipes so as to provide a desirable end clearance. This clearance permits a desirable limited axial floating movement of the coupling during operation of the apparatus to enable the coupling to move as needed with thermal expansion that may develop in the coupled components. This limited movement also enables assembly and disassembly of the coupling without disturbing either of the related coupled components. To assemble the coupling, each pipe section after having been first disconnected from the spacer **141** is inserted in its respective inlet or outlet pipe connection until limited by the related internal shoulder **143**. When this is done, sufficient space will remain between the end flanges to allow the spacer and gaskets to be loosely assembled between them. The flanges, spacer and gaskets are then bolted and drawn tightly together. When disassembling the coupling, the spacer is first unbolted and, together with the gaskets is slipped free of the flanges. The resultant space developing between the flanges will be sufficient to allow the pipe sections to be axially withdrawn from their respective pipe connections. A special advantage of this arrangement is that the short coupling is the only piping required between the discharge end of the scroll and the inlet of the related intercooler unit.

The intercooler unit **128** (FIGS. 1–3 and 15–17) is also of decided advantage in this art. It includes a cylindrical can or shell **144** having a flange **145** about its open end which is removably bolted to a complementary flange **146** of a covering header **147**. Disposed within the shell is a pair of heat exchangers or cooler units **148**. These are of rectangular configuration, superimposed or stacked one above the other. Each cooler unit has a finned tubular core **149**. The fins **151** are plates extending vertically from the rear to the front of the core; the tubes **152** of the core extend transversely through the fins and are fixed in a pair of end plates **153**. A separate water jacket or manifold **154** is bolted over each end of the core. Each manifold has an identical pair of end mounting flanges **155**, one flange of which has a passage **156** serving as an inlet for admitting fluid coolant through the manifold to the tubes of the finned core; and the other of which has a similarly located passage (not shown) serving as an outlet at the opposite end of the core for the coolant. The cooler units are individually supported by means of their flanges and bolts to the header **147**.

The header **147** is a casting formed to guide with a minimum of interference the heated compressed air entering its inlet pipe **127** over the exterior of the cooler units to the rear of the shell. This air will then flow forwardly through the finned cores and finally exit through a discharge pipe **157** of the header. The header has an outer wall **158** of general cup-form. The wall of the

discharge pipe **157** of the header continues as part of the casting for a short distance into the interior of the header to define the neck of a throat or duct **159** defined by an inner wall **161**. The contoured wall of the throat diverges rearwardly in spaced relation to the outer wall and finally terminates at the rear of the header in a frame or grate defined by a group of ribs **162**, **163**. The several ribs **162**, **163** define a squared central opening **164** into the throat. The several ribs extend in the manner of chords across the rear of the header. They are made integral at their ends with the outer wall of the header to provide a good support and rigidity for the rear of the inner wall **161**. The ribs also define with the outer wall of the header a group of chord openings **165**. The latter communicate with the common space or inlet duct **166** separating the inner and outer walls. This space connects with the inlet pipe **127**. The vertical chord ribs **163** are relatively broader than the others **162**. They serve as supporting mounts to which the end flanges **155** of the cooler units are removably bolted. A fluid coolant inlet port **167** in the header connected to the discharge end of a circulating pump (not shown) communicates through a passage **168** in one of the vertical ribs with a pair of ports **169**, each registering with a separate one of the inlet ports **156** of the cooler units; and an exit port **171** at the opposite side of the header connected to the intake end of the coolant pump communicates through a similar passage **172** of the other vertical rib with a pair of ports **173**, each registering with a separate outlet port (not shown) in the manifolds **154** (FIG. 17) at the right end of the cooler units.

The squared rear opening **164** of the header registers with the perimeter of the stacked cooler units **148**. A baffle plate **174** abutting the end face of the upper rib **162** of the header overlies the core of the upper cooler unit and rests at its ends upon the top walls of the related end manifolds. Clamps **175** fastened to the manifolds retain the position of the baffle plate. A second baffle plate **176** is similarly disposed and retained relative to the underside of the lower cooler unit. By this arrangement the upper cooler unit is closed over at its top; the bottom cooler unit is closed over at its bottom; and the sides of both cooler units are closed over by their manifolds **154**. Accordingly, both cooler units are uncovered only at their front and rear ends. The cooler units extend axially from their flanged mountings freely into the shell **144**. The free space in the shell above, below, at the sides, and to the rear of the cooler units communicates with the chord openings **165** of the header; and the interior of the shell communicates through the finned cores with the squared opening **164** of the header. Accordingly, it can be seen by this advantageous construction that heated compressed air entering the inlet pipe **127** will flow through the duct **166** defined between the inner and outer walls of the header to the chord openings **165**. It will then be guided from the openings **165** by the baffle plates and exterior surfaces of the manifolds over the exterior of the cooler units to the rear of the shell. The rear wall surface **177** of the shell will smoothly further guide the air stream forwardly through the finned cores to the squared opening **164** through which the cooled air will pass to the discharge pipe outlet. By this arrangement the air flow through the coolers is accompanied by a minimum of undesirable interference, and the air stream in passing through the finned cores traverses the full axial length of the walls of the fins. Moisture condensed out of the moving air drops to the bottom of the throat **159** where it is caught in a sump **178** and drained through an outlet **179**.

The discharge pipe **157** of the intercooler unit is connected by means of a floating coupling **181** (FIG. 1), in the nature of the coupling **126** earlier described, with a short axial inlet suction pipe **182** in the scroll cover **183** of the impeller case of a second compressor stage B, similar to that just described, except for size.

The gear casing **20** is here designed to accommodate, as earlier mentioned, four compressor stages, one at each of the locations A, B, C and D (FIG. 4). Each is similar to that of the first, except for size. Each is similarly provided with a compressor impeller assembly unit or cartridge as that earlier described, which is similarly mountable in the gear casing for association of its pinion with the bull gear. The several stages are angularly positioned about the gear case, as indicated by their locations A, B, C and D, in desirable spaced relation to one another to fairly distribute their load upon the supporting gear casing. The air intake suction pipe **89** of the first or initial stage A is open to atmosphere for its source of air; whereas the intake suction pipe of each of the other stages is connected to the discharge pipe of a separate intercooler unit. This is a straight connection providing a straight approach for air to the impeller without bends. This leads to best flow conditions and high impeller efficiency. Further, the discharge pipe **184** of the final stage D does not connect with an intercooler. Accordingly, the apparatus comprises four stages of compression operating off a common driving gear, and three stages of cooling. The intercoolers of the several stages and their mode of connections to the several stages are similar to that already described. It is understood that the number of stages may be varied, and the gear casing may be varied in size accordingly.

The impeller **87** of the first stage A and its torque transmitting pinion **46** are larger than those of the other stages. The size of the impellers proportionately decreases with each suceeding compressor stage B, C and D in accordance with the state of the air being compressed. The sizes of the related pinions also progressively decrease so as to vary the speed of the impellers as needed. Accordingly, each stage is proportioned in size to the others. This arrangement enables the impeller of the first stage to operate at high speed to induce into its case a large volume of air. As this air progressively passes from stage to stage its pressure and density increases. The interconnecting piping between the scrolls and the intercoolers are also proportionately reduced in diameter as needed.

It is also to be noted that the impeller cases and the intercooler units with the interconnecting piping are all located to the same side of the gear casing. This is of decided advantage in that it provides for compactness. It also enables the use of relatively short interconnecting piping, thus reducing the overall air flow circuit and increasing the output efficiency of the overall apparatus. It is also to be noted (FIG. 3) that two of the intercoolers **128** and **185** (FIGS. 1–3) are supported by foot flanges **21***a* in side by side relation; and that one of the latter two intercoolers has a pair of upper side flanges **186** upon which corresponding flanges **187** of the third intercooler **188** are supported to provide a compact association of the three intercoolers. In this compact arrangement the gear casing **20** is centered substantially axially relative to the three intercoolers and is of such diameter that portions of the peripheral flanges **145** of all three intercoolers lie in opposed relation to portions of the border flanges **25**, **26** of the gear casing so that tie-rods **189** extended from the casing to each of the intercooler units serve to strengthen components of the apparatus to one another. The tie-rods serve to reduce the load passing from the connecting piping of the intercoolers and the gear case to the flanged supporting feet **21**, **21***a* of the apparatus.

The mounting arrangement of the compressor impeller assembly unit (FIGS. 7, 8) relative to the gear casing is also to be noted. Substantially the full support of the unit is transmitted through the bearing block to the gear casing; and the bearing block provides a balanced load upon the casing, distributed substantially in equal degree through the bearing block to both plates of the gear casing.

Branch line **73** of the lube system serves to feed hydrostatic lube fluid to the small bearing of the bearing block of each of the compressor impeller assembly units mounted in the casing. This branch extends (FIGS. 4, 6) from its individual inlet port **84** at the gear casing and the coupling clamp block **72** in opposite directions to feed the several impeller units at locations A, B, C and D. The branch line is supported to the interior surface of the related gear casing plate **24**. The other branch line **83** of the lube system serves to feed hydrostatic fluid to the large bearing portion of the bearing block of each of the compressor impeller assembly units; and it is similarly arranged about the interior of its related gear casing plate **23** and to its individual inlet feed port **84***a*.

It is to be further noted that the mounting arrangement of the intercooler units is such that they may be individually and without difficulty disconnected from the apparatus.

What is claimed is:

1. In a centrifugal gaseous medium compressor including a gear casing having opposed front and rear walls secured together to define a chamber between them, and a bull gear supported for rotation in the chamber, the casing being formed to provide an opening extending transversely of both walls of the casing having an axis parallel to that of the gear; the improvement comprising a compressor impeller assembly cartridge removably mounted as such to the casing including an impeller shaft, a bearing having a slide fit in the opening rotatably supporting the shaft in both walls and having a bifurcation between its ends, a pinion located in the bifurcation on the shaft having direct engagement with the bull gear, means determining the position of the bifurcation so that its bottom is above the pinion, and means for directing lubricant fluid along the shaft into the bifurcation at opposite ends of the pinion.

2. In a centrifugal gaseous medium compressor including a gear casing having opposed front and rear dished walls secured together to define a chamber between them, and a bull gear supported for rotation in the chamber, the casing being formed to provide a transverse opening having an axis parallel to that of the gear, the improvement being a compressor impeller assembly cartridge having a slide fit in the opening, the cartridge comprising: a shaft carrying an impeller at one end, hydrostatic bearing means supporting the shaft in the opening, a pinion on the shaft having direct engagement with the bull gear, mounting means removably mounting the cartridge to a wall of the gear casing, fluid sealing means between the impeller and one end of the hydrostatic bearing means, thrust means adjacent the other end of the hydrostatic bearing means, and a retaining nut on the shaft adjacent the thrust means.

3. In a centrifugal gaseous medium compressor including a vertically split circular gear casing having opposed front and rear walls defining a chamber between them, a bull gear supported axially of the casing for rotation in the chamber, a bore of small diameter in the front wall at a level above the periphery of the bull gear, and a bore of larger diameter in the rear wall having an axis aligned with that of the small bore and parallel to that of the bull gear; a compressor impeller assembly unit comprising: a cylindrical hydrostatic oil bearing block having a bifurcation between its ends defining a pair of opposed bearings one larger in diameter than the other, the smaller one having a slide fit in the small bore, the larger having a slide fit in the large bore and the bifurcation spanning the bull gear, a radial flange terminating the large bearing abutting the exterior of the rear wall of the casing, an impeller shaft rotatably supported in the bearings carrying a compressor impeller at one end and projecting at its opposite end beyond the bearing block, thrust means retained on the projecting end having cooperation with the adjacent end of the block to prevent endwise escape of the shaft from the block, a baffle seal plate axially surrounding the shaft rearwardly of the impeller and abutting the flange, and a pinion carried by the shaft in the bifurcation having meshed engagement with the bull gear.

4. In a centrifugal gaseous medium compressor according to claim 3, wherein there is provided an impeller case in which the impeller is received removably mounted to the exterior of the rear wall of the gear casing having an abutment restraining the compressor impeller assembly unit against axial release in a rearward direction from the gear casing.

5. In a cenrtifgual gaseous medium compressor according to claim 3, wherein a guide pin projecting from the exterior of the rear wall of the gear casing is received in a complementary hole of the flange of the bearing block whereby the specific angular position of the bearing block to the gear casing and the bull gear is determined and the bearing block is restrained against relative rotation.

6. In a centrifugal gaseous medium compressor according to claim 3, including means for feeding highly pressurized lubricant radially through each of the bearings to the surface of the shaft, and sealing means between the impeller and the flange of the bearing block having a first stage providing a tortuous passage axially of the baffle seal plate terminating in a vent for air leaking from the impeller case around the shaft, and having a second stage passage adjoining the first stage providing a second tortuous passage axially of the baffle seal plate terminating in a further vent.

7. In a centrifugal gaseous medium compressor according to claim 6, wherein the sealing means comprises a tubular seal member fitted fast about the shaft axially of the baffle seal plate having a plurality of groups of parallel peripheral knife edges, each group being spaced from the other by an annulus, an abradable resilient tubular member seated fast in the baffle seal plate sleeving over and bearing upon the knife edges, a vent passage extending upwardly through the baffle seal plate communicating through a hole of the tubular member with one of the annuli, and a second vent passage extending downwardly through the baffle seal plate communicating through a second hole of the tubular member with another annulus.

8. In a centrifugal gaseous medium compressor according to claim 6, wherein the lubricant feeding means includes a lube gear pump operable by the shaft of the bull gear having an inlet connection with a sump and an outlet connection with the bearings.

9. In a centrifugal gaseous medium compressor according to claim 6, wherein the bearing block has leakage around the shaft from both bearings into the bifurcation, and there being a clearance between the ends of the pinion and the opposing walls of the bifurcation permitting such leaking fluid to be centrifugally thrown by the shaft to the bottom of the bifurcation and as a consequence splashed about the pinion and bull gears.

10. In a centrifugal gaseous medium compressor according to claim 6, wherein a narrow radial cavity is defined about the shaft between the baffle seal plate and the bearing block having communication through a group of axial drain holes in the bearing block with the bifurcation, and a collar formed at one end of the tubular seal member rotates in this cavity causing lubricant leaking around the shaft from the large bearing to the cavity to be centrifugally thrown towards the end of the cavity, and inclined wall means is formed about the end of the cavity to deflect the thrown lubricant into the drain holes.

11. In a centrifugal gaseous medium compressor according to claim 4, including a scroll fitted to the impeller case defining with the impeller case an annular radial passage about a peripheral exit end of the impeller for conducting air flow discharged from the impeller into the scroll; air flow diffuser means comprising a flat annular plate seated in the radial passage in surrounding relation to the exit end of the impeller, an outer annular row of long air flow diffuser vanes arranged about a face of the plate each at a predetermined angle to the exit end of the impeller providing an angular succession of air flow passages between the vanes across the face of the plate, and an inner annular row of relatively short air flow turning vanes having negligible air diffusing effect arranged about the face of the plate each at an angle to the exit end of the impeller corresponding substantially to that of the long vanes, the inner row of short vanes being offset angularly relative to the row of long vanes and having their leading edges in close predetermined spaced relation to the exit end of the impeller, the short vanes serving to turn the air stream leaving the impeller in the direction of the long vanes and the passages defined between the latter.

12. In a centrifugal gaseous medium compressor according to claim 11, wherein the long and short vanes are in the form of air-foils, and the air flow passages between the long vanes are each in extension of an angle corresponding substantially to the flow angle of the air stream at the exit end of the impeller.

13. In a centrifugal gaseous medium compressor according to claim 3, wherein the thrust means is a collar mounted upon the shaft having one face in opposed relation to the said end of the block, lube passage means is provided through the block to said face, and ports are provided through the collar communicating said one face with an opposite face of the collar.

14. In a centrifugal gaseous medium compressor according to claim 4, including a scroll fitted to the impeller case having an integral inlet suction pipe communicating with the impeller and an integral discharge pipe communicating through the scroll with the exit end of the impeller; an intercooler unit having an integral inlet pipe; and a floating coupling connecting the discharge pipe of the scroll with the inlet pipe of the intercooler unit, the coupling comprising a first pipe section slidably fitted at one end in the discharge pipe of the scroll including an O-ring seal having a sealing relation to the discharge pipe, a second similar pipe section having a similar arrangement in the inlet pipe of the intercooler unit, a flange terminating the other end of each pipe section, a spacer disposed between the flange, and fastening means removably securing the spacer and flanges together, the coupling having limited endwise floating movement relative to the discharge and inlet pipes, the overall distance between the flanges upon removal of the spacer being sufficient to permit axial withdrawal of either pipe section from the related pipe in which it has been inserted.

15. In a centrifugal gaseous medium compressor according to claim 4, including a scroll fitted to the impeller case having an inlet suction pipe communicating with the impeller and having a discharge pipe for discharging air leaving the impeller, and a heat exchange unit for receiving and cooling air discharged from the scroll, the heat exchange unit comprising: a cylindrical can open in its forward end, a cup-form header having a rear end detachably fastened over the open end of the can, an inlet pipe to the header, a grate formation at the rear of the header defining a large central opening and a plurality of ducts about the central opening all opening directly into the can, a common passage through the header communicating the plurality of ducts with the inlet pipe, a discharge pipe having communication with the central opening, and finned cooler means having an open front exit end registering with the central opening and having a rear entrance end, means removably fastening the cooler means to the grate formation, the cooler means extending axially from the grate formation into the can in spaced relation to the surrounding wall area of the can, plate means overlying the top, bottom and the side areas of the cooler means, and the fins of the cooler means being upright plates extending from the front to the rear, whereby air passing through the plurality of ducts of the grate formation flows over the plate means of the cooler means to the rear of the can and then flows through the cooler

means forwardly over the full length of the fin plates to the exit end thereof into the central opening to the discharge pipe.

16. In a centrifugal gaseous medium compressor according to claim 3, wherein a pair of baffle plates are arranged within the casing in close spaced relation to opposed faces of the body of the bull gear so as to reduce windage.

17. A centrifugal gaseous medium compressor comprising a gear casing having opposed dished front and rear walls secured about their marginal areas to one another defining a chamber between them, a bull gear supported axially of the casing for rotation in the chamber, a plurality of orderly arranged openings in the gear casing each in order having a proportioned size relation to the other, a separate impeller compressor assembly unit slidably fitted in each opening having an impeller shaft pinion disposed within the chamber in meshed engagement with the bull gear, a separate scroll housing removably mounted to the gear casing in association with a separate one of the impeller compressor assembly units for discharging air flow leaving the related impeller compressor unit, each scroll housing having an inlet suction pipe communicating axially with the related impeller compressor assembly unit and having a discharge pipe, a group of separate heat exchange units one less than the number of impeller compressor assembly units, each exchange unit having an inlet pipe and a discharge pipe, the inlet pipe of each heat exchange unit having a floating pipe coupling connection with the discharge pipe of a separate one of the scroll housings with the exception of the last in the order of the impeller compressor assembly units, and the discharge pipe of each heat exchange unit having a straight pipe connection axially with the inlet suction pipe of each of the scroll housings with the exception of that of the first in the order of the arrangement of the impeller compressor assembly units, and the impeller compressor assembly units having in the order of their arrangement a proportioned size relation to the others.

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CERTIFICATE OF CORRECTION

Patent No. 3,424,372 January 28, 1969

Ernest W. Blattner et al.

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

Column 1, line 47, "read y" should read -- readily --. Column 2, line 72, cancel "extends". Column 5, line 10, "anular" should read -- annular --; line 56, "later" should read -- latter --. Column 7, line 9, "and" should read -- an --. Column 9, line 31, "suceeding" should read -- succeeding --; line 63, "strengthen components" should read -- strengthen the common support of the several components --. Column 11, line 9, "cenrtifugally" should read -- centrifugally --.

Signed and sealed this 24th day of March 1970.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

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Commissioner of Patents