April 2, 1968 G. ZOEHFELD 3,375,970

STAGED COMPRESSORS

Filed May 25, 1966

4 Sheets-Sheet 1

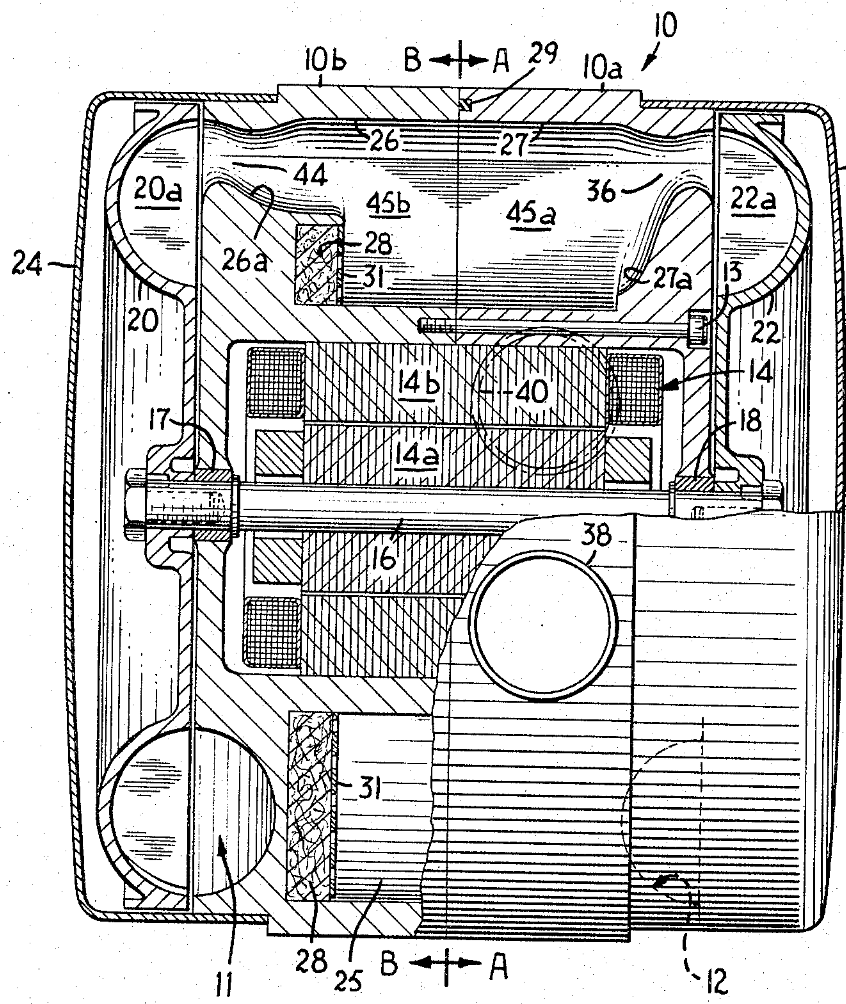

FIG. 1

INVENTOR.
GUNTHER ZOEHFELD

BY

Brumbaugh, Free, Graves & Donohue

his ATTORNEYS

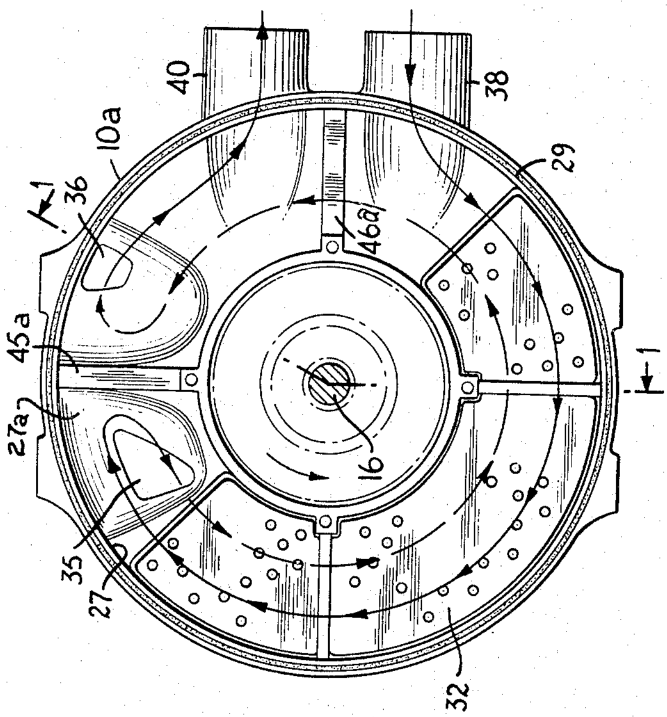

FIG. 2A

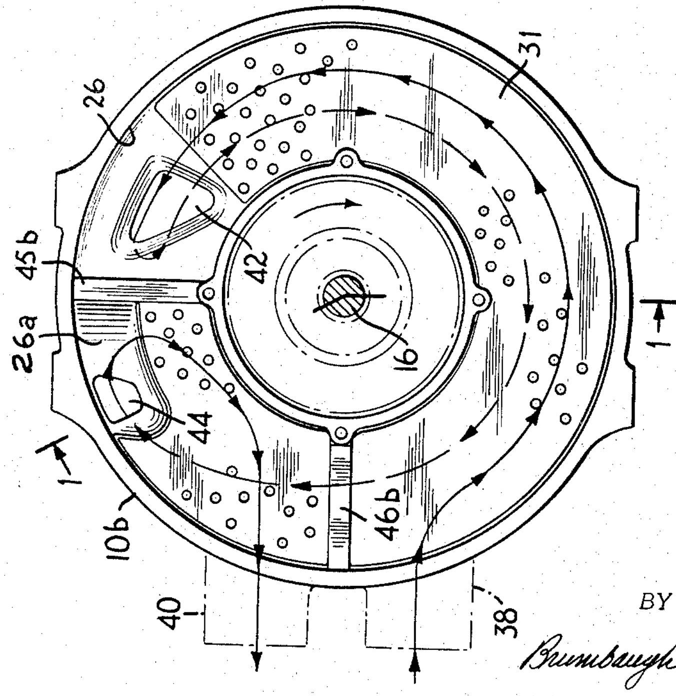

FIG. 2B

INVENTOR.
GUNTHER ZOEHFELD
BY
Brumbaugh, Free, Graves & Donohue
his ATTORNEYS

April 2, 1968 G. ZOEHFELD 3,375,970

STAGED COMPRESSORS

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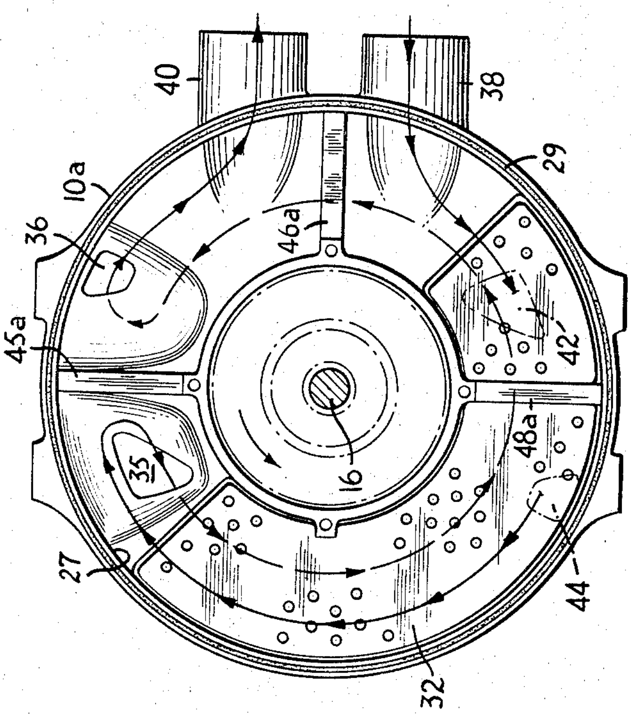

FIG. 3A

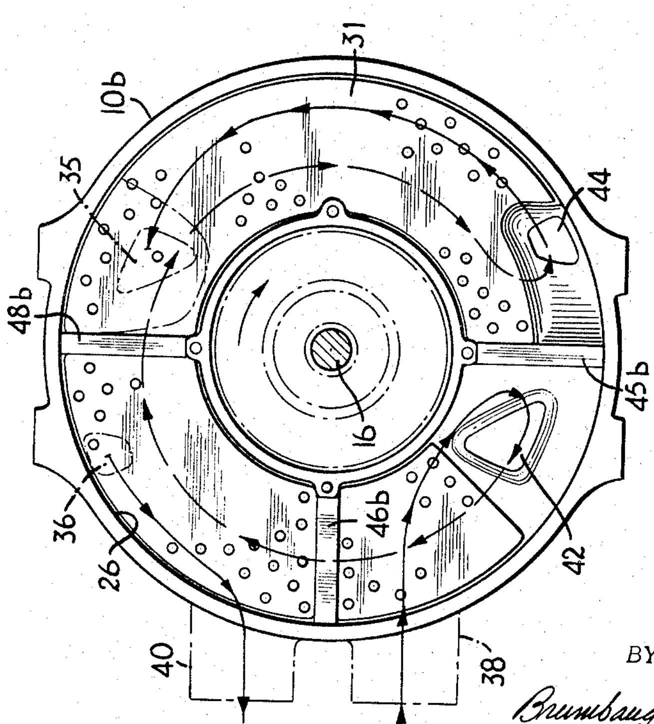

FIG. 3B

INVENTOR.
GUNTHER ZOEHFELD

BY

Brumbaugh, Free, Graves & Donohue
his ATTORNEYS

April 2, 1968 G. ZOEHFELD 3,375,970

STAGED COMPRESSORS

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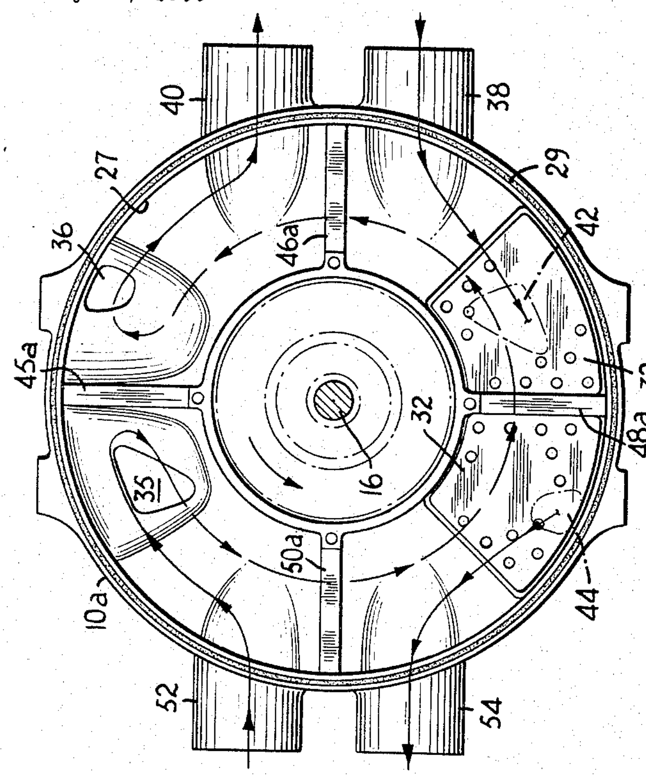

FIG. 4A

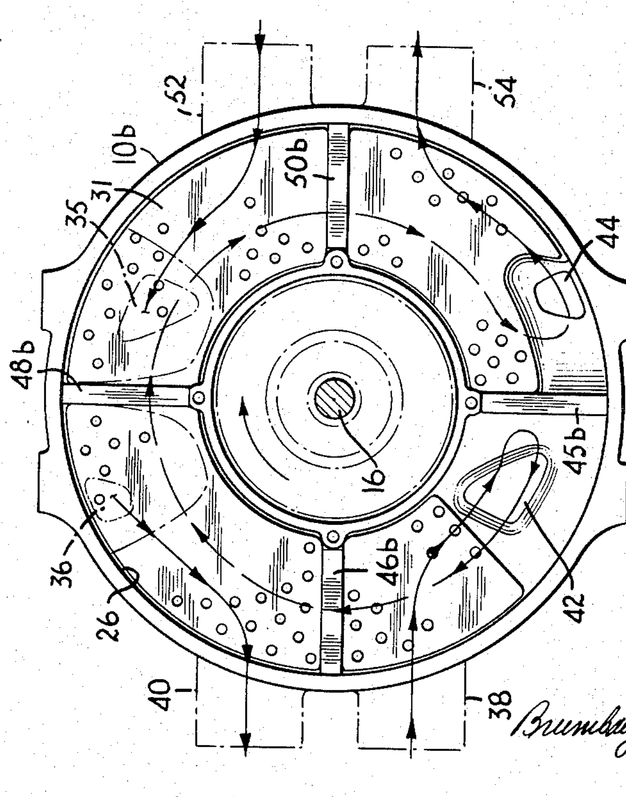

FIG. 4B

INVENTOR.
GUNTHER ZOEHFELD

BY

Brumbaugh, Free, Graves & Donohue

his ATTORNEYS

United States Patent Office

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3,375,970

STAGED COMPRESSORS

Gunther Zoehfeld, West Hurley, N.Y., assignor to Rotron Manufacturing Company, Inc., Woodstock, N.Y., a corporation of New York

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13 Claims. (Cl. 230—117)

ABSTRACT OF THE DISCLOSURE

A regenerative compressor including a motor and a housing, the housing having a pair of annular compressor chambers and a generally annular central cavity surrounding the motor and disposed between the chambers. Each chamber has associated therewith an impeller disposed for coaxial rotation by the motor to generate fluid flow in each chamber between an inlet passage and an outlet passage communicating with that chamber and the central cavity. The housing includes an intake port and an exhaust port, each of which communicates with the central cavity for receiving and exhausting the fluid to be compressed. Baffles disposed in the central cavity isolate the respective pairs of inlet and outlet passages to each of the compressor chambers and segment the central cavity into a plurality of secondary chambers so that, by selectively placing the baffles, the compressor can be operated to establish independent, parallel or series fluid flow between the intake and exhaust ports.

The present invention relates to compressors containing two or more independent compressor stages which are adapted to be connected for parallel, series, or independent operation. In particular, the invention deals with improved regenerative compressors of this type which are readily manufactured from a few basic components requiring only the simplest modification to yield either parallel, series or independent staging of individual compressor stages contained within a unitary integrated unit.

The concept of interconnecting two or more individual fluid compressors or pumps in parallel or series to obtain either increased flow volume or fluid pressure is, of course, well known. Generally speaking, however, with most types of regenerative compressors, this involves the coupling together of completely separate units through valves, ducts, etc. One obvious disadvantage of using two separate units is that routing of fluid flow for the different compressor staging arrangements introduces additional equipment at the sacrifice of compactness. Furthermore, the manufacture of two individual units instead of one is often economically impractical.

In an attempt to mitigate somewhat the expense and bulk of staging two or more essentially independent compressor units, prior practice has been to power each of the units from the shaft of a common power plant such as a motor or turbine. However much of an improvement this has been, there has remained a requirement for a basic versatile multi-stage compressor unit which lends itself well to economic production and which, at the same time, meets increasingly important requirements for maximum compactness.

It is therefore among the objects of this invention to provide an improved basic compressor unit of the type having separate compressor stages integral therewith and which overcomes the disadvantages of known compressors.

A further object of the invention is to provide a unit of this type in which the separate stages may be interconnected for independent, parallel or series fluid flow through the unit.

A further object of this invention is to provide a compressor containing two separate interconnectable compressor stages arranged to preserve the compactness of the unit.

In brief, these and other objects of the invention are attained in a compressor unit in which a housing is provided with a generally annular central cavity surrounding a compressor motor. A circular compressor chamber is located at either end of the housing and is associated with an impeller disposed for coaxial rotation with the motor to generate fluid flow between inlet and outlet passages connecting each compressor chamber with the central cavity. Various modes of staging are realized by segmenting the cavity into two or more secondary chambers, each of which communicates with at least one of the inlet and outlet passages leading to the respective compressor chambers. The secondary chambers are disposed, relative to the inlet and outlet passages, to direct fluid flow through the individual compressor stages in the desired manner.

In a preferred form of the invention, the housing is formed with first and second members each having a generally annular channel divided into inlet and outlet portions communicating with respective inlet and outlet passages. When the housing members are assembled, the channels form a central cavity which surrounds the motor. In this embodiment, the two housing members can be rotatably positioned so that the inlet and outlet portions of the channel in each member are disposed to direct fluid flow to a desired one of the inlet and outlet passages in the other member to achieve various modes of staging.

For a better understanding of the invention, together with additional advantages thereof, reference may be made to the following detailed description, and to the drawings, in which:

FIGURE 1 is a cross-sectional view of a basic compressor unit constructed in accordance with the invention, taken along the lines 1—1 in FIGURES 2A and 2B;

FIGURES 2A and 2B are plan views of the sections of the compressor housing taken generally in opposite directions from the lines A—A and B—B, respectively, in FIGURE 1, and show the segmenting arrangement of the central cavity for parallel connection of the individual compressor stages;

FIGURES 3A and 3B are plan views of the sections of the compressor housing taken generally in opposite directions from the lines A—A and B—B, respectively, in FIGURE 1, and show a segmenting arrangement of the central cavity for series connection of the individual compressor stages; and

FIGURES 4A and 4B are plan views of the compressor housing sections taken generally in opposite directions from the lines A—A and B—B, respectively, in FIGURE 1, and show a central cavity segmenting arrangement for independent operation of the individual compressor stages.

FIGURE 1 illustrates the basic features of a preferred embodiment of a compressor constructed in accordance with the invention. The compressor includes a housing **10** formed by a pair of similar housing members **10***a* and **10***b* and having toroidal or annular compressor chambers **11**, **12** of semi-circular cross section, at either outboard end of the housing. As will be apparent shortly, each compressor chamber **11**, **12** comprises the stator of an individual compressor stage. The members **10***a* and **10***b* are suitably fastened together, as by screws **13** inserted through one member **10***a* and engaging a threaded hole in the other member **10***b*. Disposed interiorally of the housing between the chambers **11**, **12** is a motor **14**, which is shown schematically to include a rotor **14***a* and stator **14***b*, the rotor being attached to a shaft **16** which is journaled for rotation in the bearings **17** and **18**.

At the ends of the shaft **16** are impellers **20, 22** each having a chamber of semi-circular cross section which is complementary to a respective associated compressor chamber **11, 12**. Each of the impellers **20, 22** is equipped with a plurality of spaced radial blades **20**a, **22**a which divide the complementary chamber of the impeller into cavities for imparting motion to the fluid. Protective covers **23, 24** at the ends of the housing **10** and enclosing the impellers **22, 20**, respectively, preclude impeller damage or misalignment and seal the housing **10** against air leakage.

Located intermediate the stator chambers **11, 12** and surrounding the motor is a central, generally annular cavity **25** which is formed by the adjacent channels **26** and **27** at the inboard ends of the housing members **10**a and **10**b, respectively. An O-ring seal **29** ensures an adequately air-tight fit between the two housing members **10**a and **10**b. Positioned along portions of the opposing faces **26**a and **27**a of the channels **26, 27** are muffling elements **28** constructed from a sound absorbent material and held in place by perforated retainers **31** and **32**, as seen also in FIGURES 2A and 2B. A more detailed explanation of the muffler arrangement and its function may be found in the copending application Ser. No. 517,412, filed Dec. 29, 1965, and assigned to the assignee of the present invention.

As will be better apparent from the subsequent figures, each of the torodial chambers **11, 12** is ducted to the central cavity **25** by inlet and outlet ducts or passages which are isolated from one another by baffles placed in the central cavity **25** to segment the cavity **25** into two or more secondary chambers. Upon rotation of the impellers **20, 22** pressure builds up in the toroidal chambers **11** and **12** between the respective inlet and outlet passages and fluid flow is generated through the compressor. Each of the torodial compressor chambers **11, 12** and the respective impellers **20, 22** associated therewith comprise an individual compressor stage which, by properly arranging the relative positions of the respective inlet and outlet passages of each of the individual stages and by selectively disposing the baffles segmenting the central cavity **25** into inlet and outlet cavity portions, may be connected for independent, parallel or series operation.

Turning now to FIGURES 2A and 2B, the relative positions of the inlet and outlet passages of each compressor stage and the position of the cavity-segmenting baffles are shown for parallel connection of the individual compressor stages. FIGURE 2A shows the right-hand housing member **10**a which includes an inlet passage **35** and an outlet passage **36**, both of which extend from the channel **27** into the annular chamber **12**. Also leading into the channel **27** are an intake port **38** and an exhaust port **40**, both located in a common quadrant of the annular central cavity **25**. Similarly, the left-hand housing member **10**b (FIGURE 2B) has an inlet passage **42** and an outlet passage **44** intercommunicating the hollow channel **26** and the torodial chamber **11**. As illustrated, the opposing faces **26**a, **27**a of the channels **26, 27** are contoured in the vicinity of the inlet and outlet passages to prevent excessive flow turbulence. In the drawings, the entire housing **10** is shown constructed of metal, but it is understood that contouring of the chamber and cavity surfaces may also be accomplished by casting the metal housing so that the chambers and channels are overdimensioned, and then coating the chamber and channel surfaces with a hard-setting plastic or epoxy compound to bring them to the proper dimension, while at the same time allowing the formation of smooth contours which would otherwise be difficult to attain through casting.

Located between the inlet and outlet ducts or passages of the two individual compressor stages is a baffle formed by the baffle plate sections **45**a and **45**b in each housing member and extending across the cavity **25** formed by the two hollow channels **26** and **27**. The baffle blocks any fluid flow through the cavity between the passage pairs **35, 36** and **42, 44**. A second baffle formed by the mating

baffle plate sections **46**a and **46**b is located in quadrature with the baffle plates **45**a and **45**b. The baffle plate sections **46**a and **46**b also present a barrier to fluid flow through the cavity **25** between the intake and exhaust ports **38** and **40**, thus segmenting the respective channels **26, 27** forming the cavity **25** into an inlet portion communicating with the intake port **38** and an outlet portion communicating with the exhaust port **40**.

The baffle plate sections may be either formed integrally with the housing members **10**a, **10**b, as illustrated in FIGURE 1 by the baffle sections **45**a, **45**b, or mounted to the housing members by any suitable fasteners, such as a screw (not shown) inserted through the edges of the plate section and engaging tapped holes in the opposing faces of the annular channels. Although not explicitly shown, the abutting edges of the baffle plate sections are preferably provided with a layer or gasket of resilient or sealing material to ensure a good seal and proper mating upon fastening the housing members **10**a, **10**b together.

Fluid flow patterns through the compressor are represented by the solid and broken lines, the solid lines tracing the flow path of the fluid in the cavity **25** and the broken lines indicating the flow paths through the annular compressor chambers **11** and **12**. As is apparent from the drawings, the inlet ducts **35** and **42** of the respective compressor stages each receive input flow from the intake port **38**, and the outlet ducts **36** and **44** each communicate with the outlet portion of the gravity **25** leading to the exhaust port **40**. Fluid enters through the intake port into the portion or secondary chamber of the cavity **25** joining the inlet passages **35** and **42**, and thence passes into the toroidal compressor chambers **11** and **12**. With impeller rotation in the direction of fluid flow, the fluid is compressed and emitted from the passages **36** and **44** into the portion of the cavity **25** leading to the exhaust port **40**. The two individual compressor stages therefore operate in parallel, the pressure between the inlet and outlet passages of each of the stages being equal and the total flow volume through the compressor unit being increased.

FIGURES 3A and 3B show the arrangement of the individual compressor stages for series connection. In this mode of operation, an additional baffle plate **48** made up of sections **48**a and **48**b is situated opposite the baffle plate **45**, and the left-hand housing member **10**b is rotated through 180° with respect to the right-hand housing member **10**a. The positions of the inlet and outlet ducts in the complementary housing member are designated in these and subsequent figures by phantom lines. As seen in FIGURE 3B, the baffle plate sections **48**a and **45**b separate the inlet and outlet passages **42, 44** in the housing member **10**b and create a third secondary chamber within the cavity **25** when the two halves of the compressor are assembled.

Tracing out the fluid flow patterns through the compressor, the fluid enters through the intake port **38** and then enters the inlet passage **42** in the housing member **10**b. After compression in the left-hand compressor stage, the fluid exits from the outlet passage **44** and then travels through a portion of the cavity **25** to the inlet passage **35** (FIGURE 3A) associated with the right-hand compressor stage, where the fluid is further compressed. From the outlet passage **36** communicating with the secondary chamber formed between the baffles **45** and **46**, the fluid passes into the exhaust port **40**. Fluid flow is thus routed completely internally of the compressor for both series and parallel staging.

Referring now to FIGURES 4A and 4B, independent operation of each compressor stage is achieved by the addition of a fourth baffle **50** comprised of the plate sections **50**a and **50**b, and an additional pair of intake and exhaust ports **52** and **54**, respectively. Following the fluid flow through the right-hand compressor stage, the fluid enters through the intake port **52** and inlet passage **35**, is compressed in the toridal chamber **12**, and exits from the outlet passage **36** into the secondary chamber communicating with the exhaust port **40**. None of the fluid entering the intake port **52** reaches the left-hand compressor stage, since the baffle **46** and sections **48***a*, **45***b* isolate the inlet passage **42** from the remaining inlet and outlet passages. Similarly, the baffle sections **48***a*, **45***b* and baffle **50** together isolate the outlet passage **44**, the baffle **50** and sections **45***a*, **48***b* isolate the inlet passage **35**, and the baffle **46** and sections **45***a*, **48***b* isolate the outlet passage **36**.

In the left-hand compressor section, fluid is received through the intake port **38** and passes through the inlet passage **42** into the annular compressor chamber **11** where it is compressed. Thereafter, the fluid is exhausted from the outlet passage **44** into the secondary chamber between the baffles **48** and **50** and passes out through the exhaust port **54**.

From the foregoing, it is seen that the described compressor unit is one which is extremely versatile and compact and which, therefore, combines optimum flow volume delivery with minimum equipment bulk. Moreover, since each compressor stage is ducted into a central cavity, the various modes of staging may be easily accomplished by segmenting the cavity to route the fluid flow between inlet and outlet passages in any desired manner. Conversion or manufacture of the unit for parallel, series or independent operation of the individual compressor stages is accomplished through a simple and expeditious modification performed on one or both of the basic housing members. Thus, with the addition of one baffle and relatively rotating the housing member through 180 degrees, as in FIGURES 3A and 3B, the compressor unit stages may be changed from parallel to series operation. For independently operating stages, one of the housing members is provided with an additional set of intake and exhaust ports, the other basic components of the compressor unit being the same, and each intake and exhaust port is isolated from the others by baffles.

Although the invention has been described with reference to specific embodiments thereof, many modifications and variations, both in form and detail, will occur to those skilled in the art. All such modifications and variations, therefore, are intended to be included within the scope and spirit of the invention as defined in the appended claims.

I claim:

1. In a regenerative compressor, a motor, a housing having a pair of annular compressor chambers and a generally annular central cavity surrounding the motor and disposed between the compressor chambers the cavity having two passage pairs of which each comprises an inlet and an outlet passage ducted to a respective compressor chamber, the housing further having an intake port and an exhaust port each communicating with the central cavity for receiving and exhausting, respectively, fluid flow through the compressor; an impeller associated with each of the compressor chambers and disposed for coaxial rotation by the motor to generate fluid flow between the inlet and outlet passages of the respective pairs; and means for isolating the inlet and outlet passages of the respective pairs.

2. A regenerative compressor as defined in claim **1**, in which the central cavity is segmented into a plurality of secondary chambers each communicating with at least one of the inlet and outlet passages of the respective pairs.

3. A regenerative compressor according to claim **2**, in which: the inlet passages of the respective pairs and the intake port communicate with a first common secondary chamber; and the outlet passages of the respective pairs and the exhaust port communicate with a second common secondary chamber; whereby the compressor is adapted for parallel fluid flow between the respective inlet and outlet passages.

4. In a regenerative compressor, a housing having a pair of annular compressor chambers and a generally annular central cavity disposed between the compressor chambers and provided with two passage pairs, each pair comprising an inlet passage and an outlet passage ducted to a respective compressor chamber, the housing further having an inlet port and an exhaust port each communicating with the central cavity for receiving and exhausting, respectively, fluid flow through the compressor; an impeller associated with each of the compressor chambers and disposed for coaxial rotation to generate fluid flow between the inlet and outlet passages of the respective pairs; means for segmenting the central cavity into a plurality of secondary chambers, one secondary chamber communicating with the inlet passage of one pair and the outlet passage of the other pair, a second secondary chamber communicating with the outlet passage of the one pair and the exhaust port, and a third secondary chamber communicating with the inlet passage of the other pair and the intake port, whereby the compressor is adapted for series fluid flow between the inlet and outlet passages of the separate pairs.

5. In a regenerative compressor, a housing having a pair of annular compressor chambers and a generally annular central cavity disposed between the compressor chambers and provided with two passage pairs, each pair comprising an inlet passage and an outlet passage ducted to a respective compressor chamber, the housing further having an inlet port and an exhaust port each communicating with the central cavity for receiving and exhausting, respectively, fluid flow through the compressor; an impeller associated with each of the compressor chambers and disposed for coaxial rotation to generate fluid flow between the inlet and outlet passages of the respective pairs; means for segmenting the central cavity into a plurality of secondary chambers to isolate the inlet and outlet passages of each pair from the passages of the other pair, with the intake and exhaust ports communicating respectively with the inlet and outlet passages of one pair through separate secondary chambers; and means defining a second pair of intake and exhaust ports communicating, respectively, with the inlet and outlet passages of the other pair through further separate secondary chambers, whereby the compressor is adapted for independent fluid flow between the respective pairs of intake and exhaust ports.

6. A regenerative compressor as defined in claim **1**, in which the intake and exhaust ports are located in a common annular quadrant of the central cavity.

7. A regenerative compressor comprising a motor; first and second housing members each having a compressor chamber at an outboard end thereof provided with an inlet and an outlet passage and a generally annular channel at the inboard end thereof divided into inlet and outlet portions communicating with the respective inlet and outlet passages, the channels in the first and second members forming a generally annular central cavity surrounding the motor; and a rotatable impeller associated with each compressor chamber and coaxially mounted to the motor for generating fluid flow between the respective inlet and outlet portions of each channel.

8. A regenerative compressor as defined in claim **7**, in which the inlet and outlet portions of each channel intercommunicate, respectively, with the respective inlet and outlet portions of the other channel, whereby the compressor is operable to establish parallel fluid flow between the respective inlet and outlet portions.

9. A regenerative compressor as defined in claim **7**, in which the inlet portion of one channel is disposed to receive fluid flow from the outlet portion of the other channel, whereby the compressor is adapted to establish series fluid flow between the inlet portion of the other channel and the outlet portion of the one channel.

10. A regenerative compressor in accordance with claim **7**, wherein the inlet and outlet portions of the respective channels are disposed so as to be isolated from each of the other portions, whereby the compressor is adapted to establish fluid flow between the inlet and outlet passages associated with one compressor chamber independently of the fluid flow through the inlet and outlet passages associated with the other compressor chamber.

11. A regenerative compressor as set forth in claim **7**, wherein the inlet and outlet portions of the respective chambers are divided by baffle means disposed to segment the central cavity into a plurality of separate secondary chambers.

12. A regenerative compressor as defined in claim **7**, wherein the first and second housing members are relatively rotatable.

13. A compressor unit comprising: a motor including a rotor; a housing having an annular compressor stator chamber formed integrally with the housing at either end thereof and a generally annular central cavity disposed between the stator chambers and surrounding the motor, each of the stator chambers including an inlet and outlet passage for ducting the respective chambers to the central cavity, the housing further having an intake port and an exhaust port communicating with the central cavity for receiving and exhausting, respectively, fluid flow through the compressor; and an impeller associated with each of the stator chambers and connected to either end of the rotor for coaxial rotation therewith to generate fluid flow between the inlet and outlet passages of the respective stator chambers; and means disposed in the central cavity for isolating the inlet and outlet passages of the respective stator chambers.

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HENRY F. RADUAZO, *Primary Examiner*