

Feb. 5, 1929.

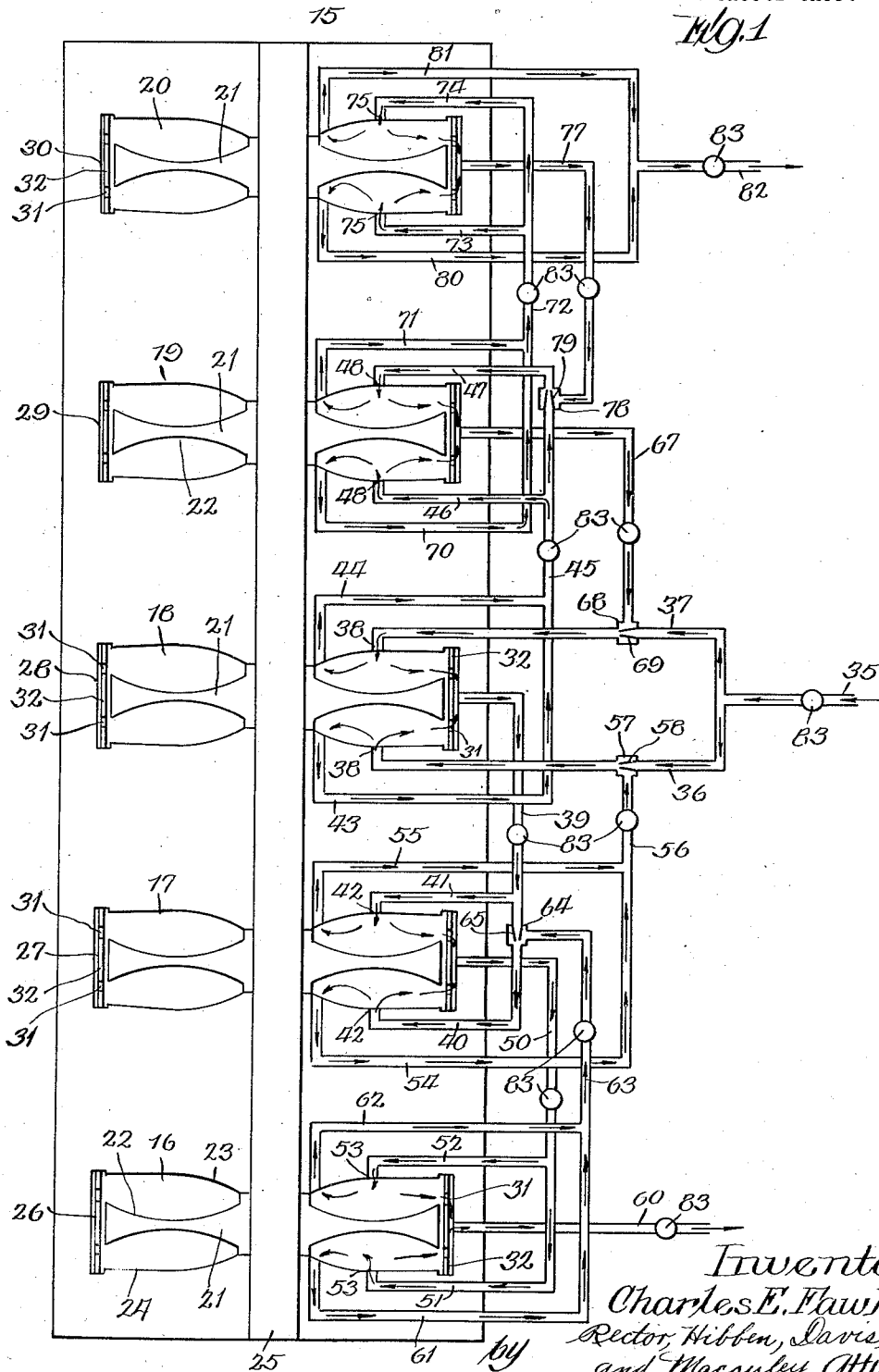
1,700,928

C. E. FAWKES

APPARATUS FOR CENTRIFUGAL SEPARATION

Filed Aug. 25, 1922

4 Sheets-Sheet 1



Feb. 5, 1929.

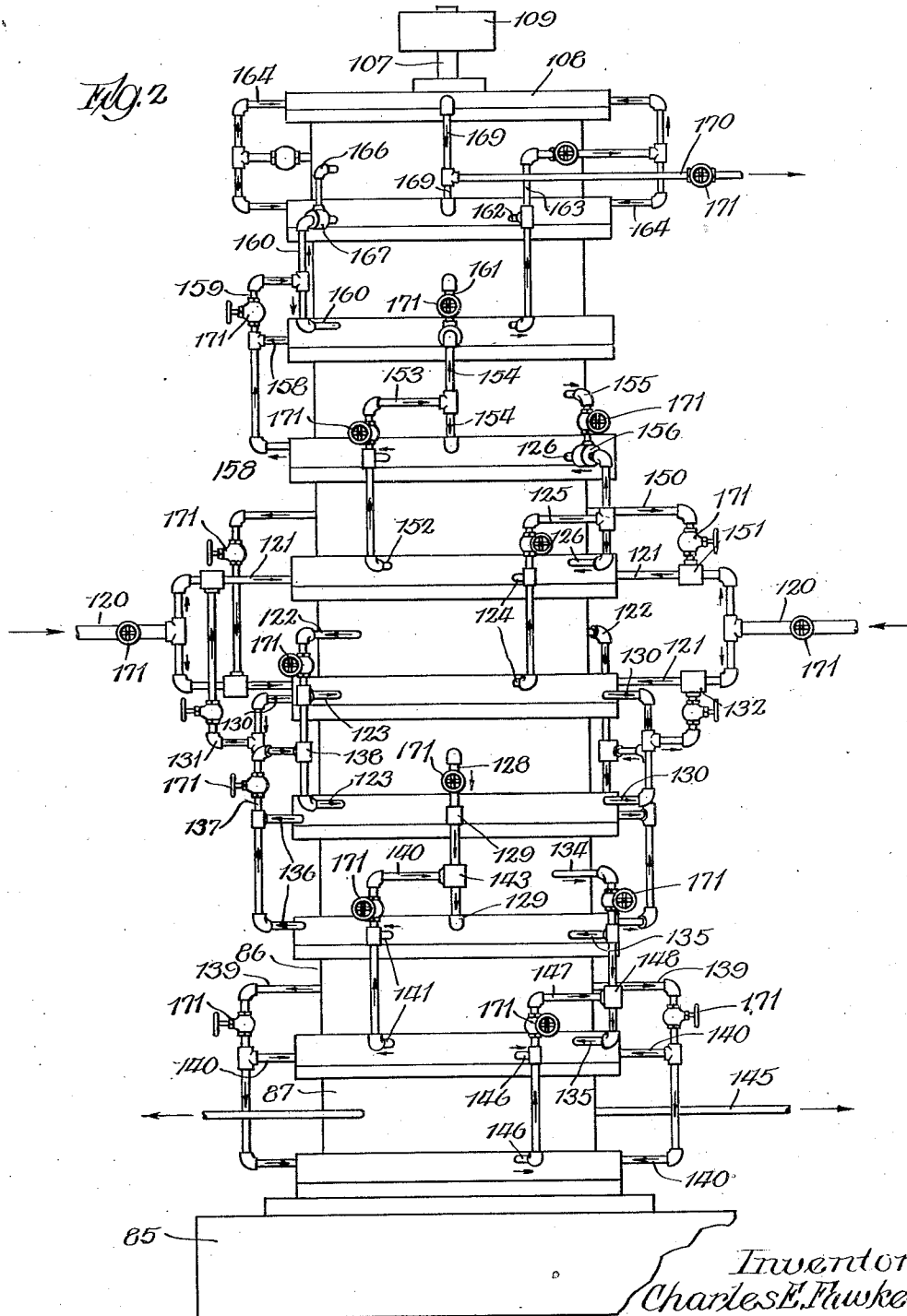
1,700,928

C. E. FAWKES

APPARATUS FOR CENTRIFUGAL SEPARATION

Filed Aug. 25, 1922

4 Sheets-Sheet 2



Inventor
Charles E. Fawkes
by Victor, Hibben, Davis, and Macaulay
Attorneys

Feb. 5, 1929.

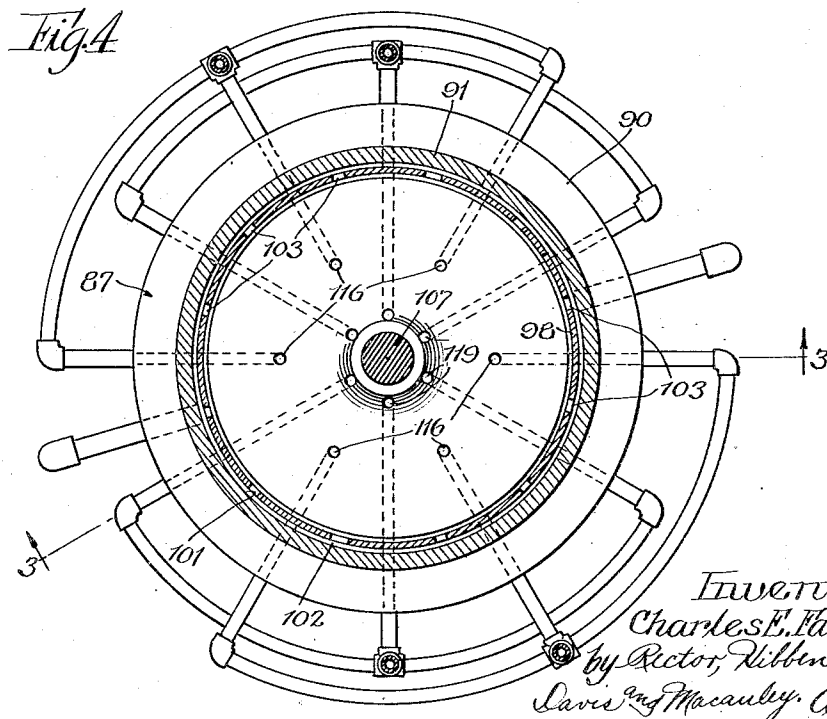
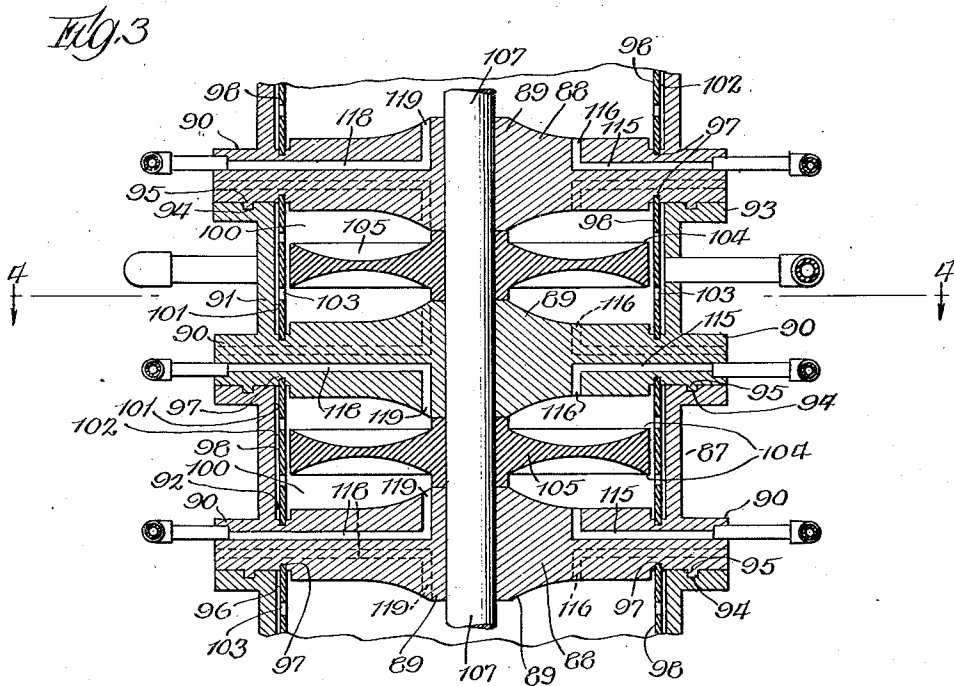
C. E. FAWKES

1,700,928

APPARATUS FOR CENTRIFUGAL SEPARATION

Filed Aug. 25, 1922

4 Sheets-Sheet 3



Feb. 5, 1929.

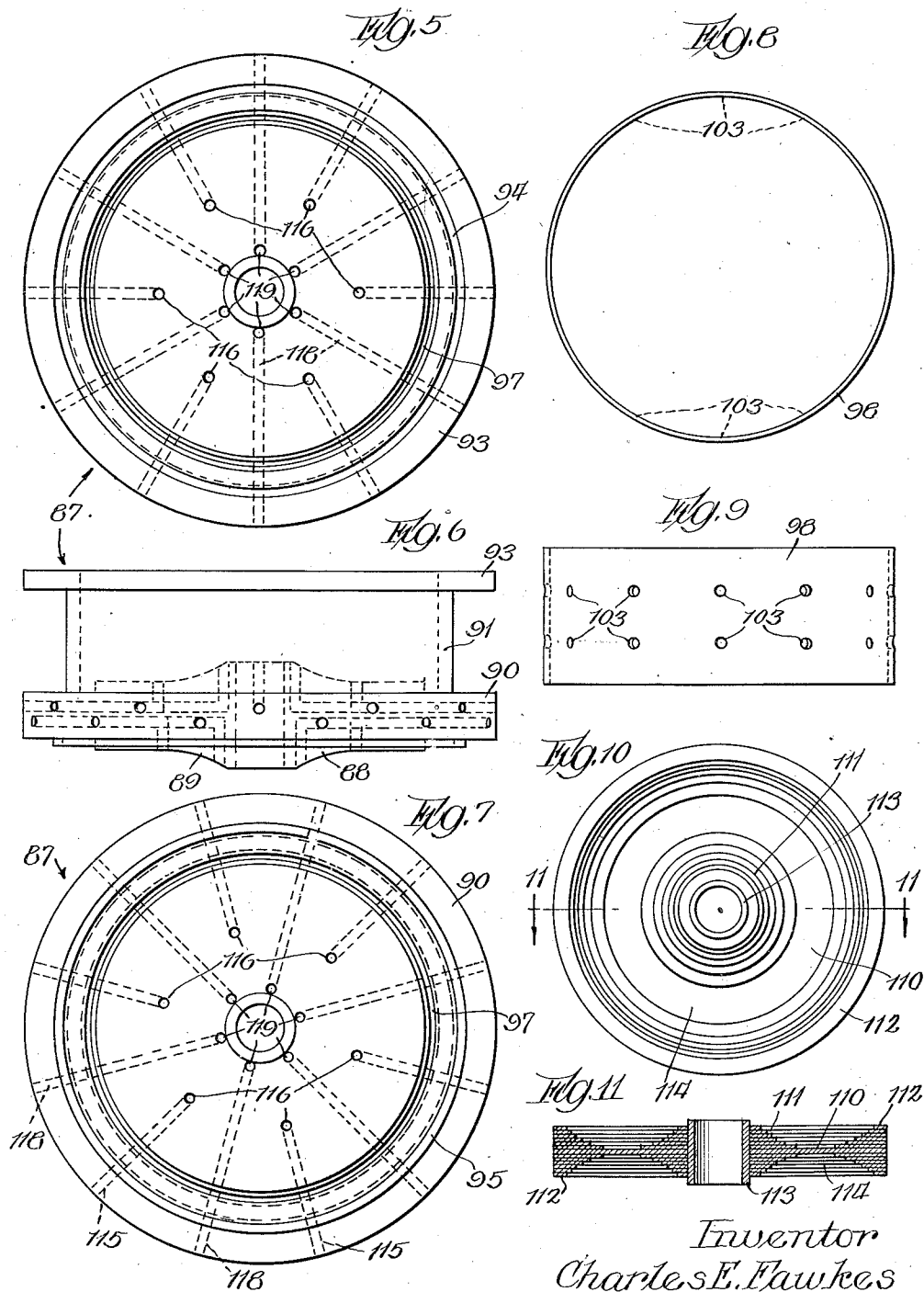
C. E. FAWKES

1,700,928

APPARATUS FOR CENTRIFUGAL SEPARATION

Filed Aug. 25, 1922

4 Sheets-Sheet 4



Inventor
Charles E. Fawkes
by Rector, Hibben, Davis, & Macaulay
Attys.

UNITED STATES PATENT OFFICE.

CHARLES E. FAWKES, OF CHICAGO, ILLINOIS.

APPARATUS FOR CENTRIFUGAL SEPARATION.

Application filed August 25, 1922. Serial No. 584,200.

This invention relates to a new process and apparatus for separating gases and liquids by centrifugal force. The invention is particularly adapted for use in the extraction of oxygen from the air but it may be employed for the continuous separation of the components of various gases and vapors, for the mechanical separation of miscible liquids, or the separation of the discontinuous phase from the continuous phase in emulsions, suspensions and dispersoids in general. The invention may be used with particular advantage in the separation of the components of fluids having relatively high molecular or ionic velocities.

An important object of the invention is to provide means for separating in a convenient and inexpensive manner the oxygen from the other ingredients of the atmosphere, thus making possible the production of a large and cheap supply of oxygen for use in connection with furnaces and other apparatus. The invention is distinguished by the fact that the components of the fluid which are to be separated are subjected to several successive centrifugal separations in a single unit machine so that the purity of each of the components separated may be increased to any desired extent by multiplying the number of stages of separation. The various objects and advantages of the invention will be apparent from the succeeding description.

The nature of the invention will be understood from the following specification taken with the accompanying drawings in which one embodiment of the apparatus for carrying out the improved process is illustrated. In the drawings,

Fig. 1 shows a somewhat diagrammatic vertical section through apparatus embodying the present invention;

Fig. 2 shows an external side elevation of apparatus embodying the invention;

Fig. 3 shows a vertical axial section through the apparatus illustrated in Fig. 2, the section being taken on the line 3—3 of Fig. 4;

Fig. 4 shows a horizontal section taken on the line 4—4 of Fig. 3;

Fig. 5 shows a plan view of one of the stationary sections of the centrifugal separator;

Fig. 6 shows a side elevation of the section illustrated in Fig. 5;

Fig. 7 shows a bottom plan view of the section illustrated in Fig. 6;

Fig. 8 shows a plan view of one of the an-

nular perforated shells forming the outer wall of each separating chamber;

Fig. 9 shows a side elevation of the annular perforated shell illustrated in Fig. 8;

Fig. 10 shows a plan view of the preferred form for gases and vapors of the rotating disc located in each separating chamber; and

Fig. 11 shows a sectional view on the line 11—11 of Fig. 10.

In the accompanying drawings the invention is illustrated as embodied in apparatus comprising a plurality of separating chambers which are arranged in series vertically, the heavier component of the fluid being treated being drawn off at the bottom of the apparatus while the lighter components are drawn off at the top, and to facilitate a clear explanation of the theory of the process and apparatus, before discussing the details of construction of the apparatus, there has been illustrated in Fig. 1 a diagrammatic representation of a form of apparatus comprising five separating chambers 16, 17, 18, 19 and 20. Each chamber has mounted therein a rotatable disc 21 provided on each of its opposite sides with an annular concave depression 22 corresponding to the similar convex projections 23 which are formed centrally in the upper and lower walls of the separating chambers around the driving shaft 25. The outer portions of the upper and lower walls of the separating chambers extend at right angles to the surfaces of the shells 32, hereinafter described. The discs 21 thus divide the separating chambers into complementary chambers 24 which are annular in form, and oblong in cross section. The discs 21 are mounted on a common shaft 25 which extends vertically and which is adapted to be driven at high speed by any suitable source of power. The chambers 16, 17, 18, 19 and 20 communicate around their outer peripheries with annular collecting chambers 26, 27, 28, 29 and 30, respectively, the communication with these chambers being established through perforations 31 formed in annular shells or cylinders 32. As the discs 21 are rotated, the motion imparted to the complex fluid in the several separating chambers results in the heavier components of the fluid being thrown outwardly into the collection chambers while the lighter components occupy the inner portions of the separating chambers from which they may be withdrawn by the means hereinafter described.

Assuming that the apparatus represented

in Fig. 1 is employed according to the process of the present invention to separate oxygen from the atmosphere, the air is supplied under pressure through a pipe 35. This pipe is provided with branches 36 and 37 which lead into opposite sides of the central separating chamber 18 in the region of medium centrifugal force, as shown at 38. The air thus introduced into the chamber 18 is subjected to the action of the rapidly rotating disc 21 mounted in that chamber with the result that the heavier component, higher in oxygen, is thrown outwardly by centrifugal force and passes through the apertures 31 into the collection chamber 28. From this collecting chamber the oxygen component passes through a pipe 39 through the branch pipes 40 and 41 which lead into opposite sides of the next lower separating chamber 17 in the region of medium centrifugal pressure, as shown at 42. The lighter components of the air separated in the chamber 18, occupying positions near the axis of the rotating disc 21, are passed off through branch pipes 43 and 44, leading from the region of minimum pressure in the chamber 18 and leading to a common pipe 45 which communicates through branch pipes 46 and 47 with the opposite sides of the next higher separating chamber 19 in the region of medium centrifugal pressure, as shown at 48. Thus the separated components of the air introduced under pressure into the chamber 18 are passed after separation into other similar chambers of the apparatus, the heavier component, higher in oxygen content, being passed downwardly into the next lower chamber 17, while the lighter nitrogen containing component is passed upwardly into the next higher chamber 19.

In the chamber 17 the heavier oxygen containing component drawn from the chamber 18 is again subjected to centrifugal separation and the heavier component resulting from this new separation, containing oxygen in greater volume concentration, passes through the apertures 31 into the annular collecting chamber 27. From this annular chamber the oxygen containing component passes through a pipe 50 to branch pipes 51 and 52 which communicate with opposite sides of the lowermost separating chamber 16 in the region of medium centrifugal pressure, as shown at 53. The lighter components resulting from the separation in the chamber 17 pass off from the region of low centrifugal pressure in that chamber through the branch pipes 54 and 55 which communicate with a pipe 56 leading to an enlargement 57 formed in the branch pipe 36 through which air is introduced to the chamber 18. In passing through the enlargement 57, the air is injected at high velocity through a Venturi nozzle so that the nitrogen containing components passing through the pipe 56 are drawn by suction into the current of air passing through the pipe 36

and are thus carried from a region of relatively low pressure back into the central separating chamber 18 against the higher pressure which prevails therein. Venturi nozzles of this form are made use of throughout the apparatus for conveying various separated compounds by suction into regions of relatively higher pressure, thus making it possible to effect the retreatment and re-separation in various stages of the components of the air which have previously been treated in succeeding stages of the process.

In the lowermost chamber 16 a further separation takes place resulting in the production of a heavier component containing oxygen of a still higher degree of concentration which is thrown outwardly and collected in the chamber 26. From this chamber the oxygen containing component is drawn off through a pipe 60 by which it may be conveyed to a furnace or other apparatus in which it is to be consumed. From the region of low pressure in the chamber 16 the lighter nitrogen containing component of the separated gas is drawn off through branch pipes 61 and 62 which lead into a common pipe 63 communicating with an enlargement 64 formed in the branch pipe 40, previously described. The oxygen containing components passing through the pipe 40 are carried through a Venturi nozzle 65 arranged opposite the outlet of the pipe 63 so that the lighter gases in the pipe 63 are drawn by suction into the pipe 40 and carried into the chamber 17 against its higher pressure in that chamber.

As previously stated, the lighter nitrogen containing components drawn from the chamber 18 are introduced through the branch pipes 46 and 47 into the next higher separating chamber 19. A further centrifugal separation takes place in the chamber 19 resulting in the oxygen containing component being forced outwardly into the annular collecting chamber 29. From this chamber this heavier component passes downwardly through a pipe 67 into an enlargement 68 formed in the branch pipe 37 through which air is supplied under pressure to the central chamber 18. The gas passes at high velocity through a Venturi nozzle 69 located in the enlargement 68 so that the oxygen containing component separated in the chamber 19 is drawn by suction into the pipe 37 and conveyed into the chamber 18 against the higher pressure in that chamber. From the region of low pressure in the chamber 19 the lighter nitrogen containing component, separated by the action of centrifugal force, passes through branch pipes 70 and 71 into a pipe 72 which leads upwardly and communicates through branch pipes 73 and 74 with the opposite sides of the uppermost separating chamber 20 in the region of medium centrifugal pressure in that chamber,

as shown at 75. As a result of the renewed centrifugal separation which takes place in the chamber 20, a heavier oxygen containing component is collected in the chamber 30 and is drawn off therefrom through a pipe 77 which extends downwardly and communicates with an enlargement 78 formed in the branch pipe 47 previously described. A Venturi nozzle 79 is located in this enlargement so that the passage of the gases through the pipe 47 creates a suction which draws in the oxygen containing component conveyed through the pipe 77, resulting in these components being carried through the pipe 47 into the chamber 19 against the higher pressure in that chamber. From the region of low pressure in the uppermost chamber 20 the lighter nitrogen containing component is drawn off through branch pipes 80 and 81 leading to a common discharge pipe 82 to which the gas, rich in nitrogen, may be discharged into the atmosphere or otherwise disposed of. In order to regulate the volume of the various fluids transferred from one chamber to the other in various parts of the system, a series of valves 83 are provided in the connecting pipes so that the flow in any particular connection may be regulated independently of the other connections.

Thus the air introduced into the apparatus 15 through the pipe 35 is subjected to a series of successive centrifugal separations with the result that oxygen of a greater or lesser degree of purity and the heavier inert atmospheric gases are discharged through the pipe 60 at the lower part of the apparatus, while the nitrogen and other lighter components of the atmosphere are discharged through the pipe 82 at the upper part of the apparatus. From the outer part of each separating chamber the heavier oxygen containing component separated in that chamber is conveyed downwardly and introduced into the next chamber below in the region of medium centrifugal pressure in that chamber where a new separation takes place resulting in the production of a heavier component containing oxygen of a higher degree of purity which is again conveyed into the region of medium centrifugal pressure in the next lower chamber. At the same time the nitrogen and other lighter components are carried from the region of low pressure in each separating chamber to the region of medium centrifugal pressure in the next higher separating chamber. The heavier components gradually conveyed toward the bottom of the apparatus are increased in purity as the successive stages of the separation are performed while the gases withdrawn from the inner regions of the separating chambers are conveyed upwardly into the next higher separating chambers contain lesser percentages of oxygen as the upper extremity of the apparatus is approached so that the gases treated in the uppermost separating chamber

consist mostly of nitrogen and the other lighter components which, after the separation of the small quantity of oxygen present, are discharged through the outlet 82.

The form of apparatus for carrying out the process described above is illustrated more in detail in Figs. 2 to 11 inclusive where the apparatus is shown as comprising a supporting base 85 having a cylindrical casing 86 extending vertically therefrom. The casing 86 is made up of a plurality of similar sections 87 adapted to interfit with each other, as shown particularly in Fig. 3. Each section 87 has a disc-like body portion 88 provided on opposite sides with central projections 89. An annular flange 90 projects outwardly from the body portion 88 of each section and a cylindrical wall 91 extends upwardly from the flange 90, being spaced outwardly from the body portion 88, leaving an annular recess 92. The upper edge of the cylindrical portion 91 of each section is provided with an outwardly directed annular flange 93, provided on its upper side with an annular groove 94 adapted to be engaged by the annular projection 95 formed on the under side of the flange 90 of the next adjacent section. The annular flanges of adjacent sections thus have an interfitting engagement with each other and, if desired, they may also be secured together by means of bolts or the like. The body portion 88 of each section extends downwardly below the outwardly directed flange 90 and the annular surface of this downwardly projecting part is spaced inwardly from the cylindrical portion 91 of the next lower section 87, thus leaving an annular recess 96 similar to the annular recess 92 formed on the upper side of each section. Mounted in the recesses 92 and 96 of the adjacent sections and engaging annular grooves 97 in the flanges 90 are a plurality of cylindrical shell members 98 each adapted to form the outer wall of one of the separating chambers 100 formed between adjacent sections of the casing. These wall members 98 are spaced inwardly from the inner annular surfaces 101 of the cylindrical portions 91 of the casings, thus forming collecting chambers 102 which communicate with the separating chambers 100 by means of apertures 103 which are formed in the members 98. The apertures 103 are arranged in rows around the members 98, as shown in Fig. 9, and are located as nearly as possible in alignment with the upper and lower peripheral edges 104 of the rotatable discs 105. These discs are mounted on a center vertical shaft 107 which is journaled in bearings formed in the central parts of the body portions 88, in the base 85 and in the upper end wall 108 of the casing 86. The shaft 107 projects upwardly beyond the upper end wall 108 and has a pulley 109 mounted thereon through which it may be driven by an electric motor or other suitable device.

Although the discs 105 have been illustrated in Fig. 3 as solid members, they may preferably be formed to secure greater frictional surface, as shown in Figs. 10 and 11, where each disc is made up of a central solid plate 110 having a series of inner rings 111 and outer rings 112 secured thereto around the hub 113. The rings 111 and 112 are gradually increased in diameter from the plate 110 longitudinally of the hub 113 in each direction, thus giving to the opposite sides of the rotatable disc a stepped formation which forms annular depressions 114 adapted to provide a large frictional surface to contact with the complex fluid and impart the greatest rotational velocity thereto near the apertures 103. The discs 105 thus divide the separating chambers 100 into separate compartments each consisting of an annular chamber of oblong cross section. The discs 105 preferably have the same outer diameter as the outer diameter of the body portions 88 so that an annular space is formed between each rotatable disc and the adjacent outer wall 98, as well as between the outer annular surfaces of the body portions 88 and the outer walls 98. As the discs are rotated by the shaft 107, the contents of the separating chambers 100 are set in motion by the frictional engagement therewith of the surface of the discs with the result that the heavier portions pass outwardly through the spaces 104 and apertures 103 into the annular collecting chambers 102.

For the purpose of introducing the materials to be separated into the separating chambers 100 of the casing 86, the body portion 88 of each section 87 is provided with a plurality of radial passages 115 which communicate at their inner ends with the chambers 100 in the region of medium centrifugal pressure, as shown at 116. Two series of these passages are formed in each body portion 88, the inner extremities of one series of passages being directed upwardly to communicate with one separating chamber 100, while the inner extremities of the other series of passages are directed downwardly to communicate with the next lower chamber 100. In addition to the passages 115, the body portion 88 of each section is provided with two series of other passages 118 which extend radially, midway between the passages 115, as shown in Fig. 4, and having their inner extremities directed parallel to the shaft 107 to communicate with the innermost parts of the chambers 100, as shown at 119. The nitrogen and other lighter portions of the air, if the machine be used for extracting oxygen, are adapted to be withdrawn through these passages 118.

The several separating chambers 100 are placed in communication with each other through a series of pipes mounted on the outer side of the casing, as illustrated particularly in Fig. 2, where the arrows indicate

the direction in which the contents of the pipes flow. The air or other fluid to be separated is introduced into the apparatus under pressure through pipes 120 located midway between the upper and lower ends of the casing. Each pipe 120 communicates through branch pipes 121 with the passages 115 leading to the region of medium pressure in the central chamber 100. From the collecting chamber 102 around this central chamber the heavier component of the separated fluid flows downwardly through pipes 122 which communicate directly with the central parts of the collecting chamber, as shown in Figs. 2 and 3. These pipes 122 lead downwardly and communicate with the branch pipes 123 leading to opposite sides of the next lower chamber 100 through the passages 115 which communicate with the next lower chamber. The lighter components of the separated contents of the central chamber 100 are withdrawn through the passages 118 leading from that chamber and communicating with branch pipes 124 which lead through a pipe 125 to the branch pipes 126, having communication with the next chamber above through the passages 115 formed in the walls of that chamber.

From the first chamber below the central chamber of the casing, the heavier separated component is withdrawn through pipes 128 which lead through branch pipes 129 to the passages 115 communicating with the second chamber below. The lighter separated component in the first chamber below the central chamber is withdrawn through pipes 130 leading from the passages 118 which open from the inner part of that chamber. These pipes 130 communicate with pipes 131 which lead to the enlarged couplings 132 which are connected in the branch pipes 121 through which air or other fluid is supplied to the central chamber. These couplings have Venturi nozzles mounted therein in the manner previously described so that the flow of fluid through the pipes 121 creates a suction which draws in the contents of the pipes 131 and discharges these contents back into the central chamber 100.

In a similar manner, the heavier separated component of the contents of the second chamber below the central one is withdrawn through pipes 134 which communicate through branch pipes 135 with the passages 115 leading to the next lower chamber 100. The lighter component of the separated contents of the second chamber below are transferred upwardly through the branch pipes 136 and the pipes 137 to couplings 138 located in the pipe 123 which leads to the next chamber above.

From the third chamber below the central part of the apparatus, the heavier separated component flows downwardly through a pipe 139 into branch pipes 140 which communicate

through the passages 115 with the lowermost chamber. The lighter separated components of the contents of the third chamber below the central part are transferred upwardly through pipes 141 and 142 to couplings 143 located in the pipes 129 which communicate with the next chamber above.

From the bottom chamber of the apparatus the oxygen or other purified fluid is discharged through pipes 145, while the lighter waste portion of the fluid is withdrawn through pipes 146 and conveyed upwardly through pipes 147 to couplings 148 located in the pipes 135 which communicate with the next chamber above.

This same method of intercommunication between the separate chambers of the casing is carried out in the same manner above the central part of the apparatus. The first chamber above the central chamber is connected to discharge the heavier separated component by pipes 150 which lead to couplings 151 connected in the pipes 121 leading to the central chamber and having nozzles located therein to create a suction by the flow of fluid into the central chamber. The lighter portions separated in the first chamber above the central part are withdrawn upwardly through branch pipes 152 and pipes 153 which lead to branch pipes 154 having communication with the next chamber above through the passages 115 located in the walls of that chamber.

The heavier component separated in the second chamber above the central part is discharged through pipes 155 into couplings 156 located in the pipes 126 and having nozzles therein to create a suction in the manner previously described. The lighter materials from the second chamber above are discharged upwardly through branch pipes 158 leading through a pipe 159 to branch pipes 160 which communicate with the next chamber above.

From this third chamber above the heavier portions are discharged downwardly through pipes 161 and through the pipes 154 leading to the next chamber below, while the lighter portions are discharged upwardly to branch pipes 162, pipes 163 and branch pipes 164 into the uppermost chamber of the apparatus.

From the uppermost chamber the heavier separated materials are discharged downwardly through pipes 166 into couplings 167 located in the branch pipes 160 which communicate with the regions of the medium centrifugal pressure in the next chamber below. The lighter separated materials in the uppermost chamber, such as nitrogen and the like, if the apparatus be used for extracting oxygen, are discharged through branch pipes 169 leading from the passages 118 and communicating with discharge pipes 170. The flow of the various fluids in different parts of

the system is regulated in this form of apparatus by means of a series of valves 171, which are located in the various pipes connecting the several separating chambers.

In the form of apparatus illustrated in Figs. 2 and 9, as well as in that explained with the diagrammatic representation of Fig. 1, there is a gradual flow of the heavier materials towards the bottom of the apparatus and a gradual increase in the density of these heavier components as the bottom section of the apparatus is approached, so that the centrifugal action of the rotating discs is supplemented somewhat by the action of gravity in the separation and flow of materials through the apparatus. The lighter components flow upwardly through the apparatus and their density gradually decreases as the top of the casing is approached, due to the successive action of the separating chambers in extracting the heavier components. The apparatus may be operated continuously at a relatively small cost to effect a continuous separation of the heavier and lighter components of gases, liquids or other fluids, and the degree of purification or the perfection of the separation may be regulated as desired by increasing or decreasing the number of separating chambers connected in series.

Although a particular form of apparatus has been shown and described in connection with the explanation of one method of carrying out the process of this invention, it will be understood that both the apparatus and the process may be varied without departing from the scope of the appended claims.

I claim:

1. In fluid separating apparatus of the class described, a plurality of closed separating chambers; means operating in each of said chambers for separating the heavier and lighter components of the fluid therein and creating regions of high and low pressure therein, means for introducing a fluid into one of said chambers, and means for conveying a separated component of said fluid in that chamber to a region of medium pressure in another of said chambers.

2. In fluid separating apparatus of the class described, a casing having a closed separating chamber, a collecting chamber having communication with the outer part of said separating chamber throughout its periphery, a rotatable member mounted in said separating chamber, means for introducing the fluid to be separated into a region of medium centrifugal pressure in said chamber, and means for withdrawing the lighter separated component of said fluid from the inner part of said chamber.

3. In fluid separating apparatus of the class described, a casing having a closed separating chamber, a shaft extending through the central part of said chamber, and a disk

mounted on said shaft, said disk and the walls of said chamber having registering annular projections.

4. In fluid separating apparatus of the class described, a plurality of closed separating chambers, means operating in each of said chambers for separating the heavier and lighter components of the fluid therein and creating regions of high and low pressure therein, means for introducing a fluid into the region of medium pressure in one of said chambers, means for withdrawing the heavier separated component from a region of higher pressure in said last mentioned chamber and conveying it to a region of medium pressure in a succeeding chamber of the series, and means for withdrawing the lighter separated component of said fluid from a region of lesser pressure in said chamber in which said separation first takes place and returning it to a region of medium pressure in another chamber of the series.

5. In fluid separating apparatus of the class described, a casing having a closed separating chamber, a rotatable member mounted in said chamber, a cylindrical member forming the outer shell of said chamber, said casing having a collecting chamber on the outer side of said outer shell, said cylindrical member having perforations forming a communication between said closed separating chamber and said collecting chamber, means for introducing a fluid into said separating chamber, and means for withdrawing the heavier component of said fluid from said collecting chamber.

6. In fluid separating apparatus of the class described, a casing comprising a series of closed separating chambers, rotatable members mounted in said chambers to set up a centrifugal action of the contents thereof, means for introducing a fluid into the region of medium pressure in the first chamber of the series, means for withdrawing the heavier separated component from a region of higher pressure in each chamber of the series and

conveying it to a region of medium pressure in a succeeding chamber of the series, and means for withdrawing the lighter separated component from a region of lesser pressure in each chamber of the series and returning it to a region of medium pressure in a preceding chamber of the series against higher pressure therein.

7. In fluid separating apparatus of the class described, a casing comprising a plurality of complementary sections, each section comprising a body portion and an annular cylindrical portion projecting transversely therefrom, means for connecting the body portion of one section to the annular cylindrical portion of the next adjacent section, a shaft journaled in the body portions of said sections, and rotatable members mounted on said shaft, each rotatable member being located in a chamber formed between the body portions of adjacent sections, said rotatable members and said body portions of said casing being provided on opposite sides thereof with annular depressions, whereby said chambers are divided into complementary parts of annular form and substantially oblong cross section.

8. In fluid separating apparatus of the class described, a casing comprising a plurality of complementary sections, each section comprising a body portion and an annular cylindrical portion projecting transversely therefrom, and means for connecting the body portion of one section to the annular cylindrical portion of the next adjacent section, a shaft journaled in the body portions of said sections, rotatable members mounted on said shaft, each rotatable member being located in a chamber formed between the body portions of adjacent sections, the body portions of said casing having passages leading therethrough to the outer part of said casing, and means for connecting the passages leading from one chamber to the passages leading from another chamber.

CHARLES E. FAWKES.