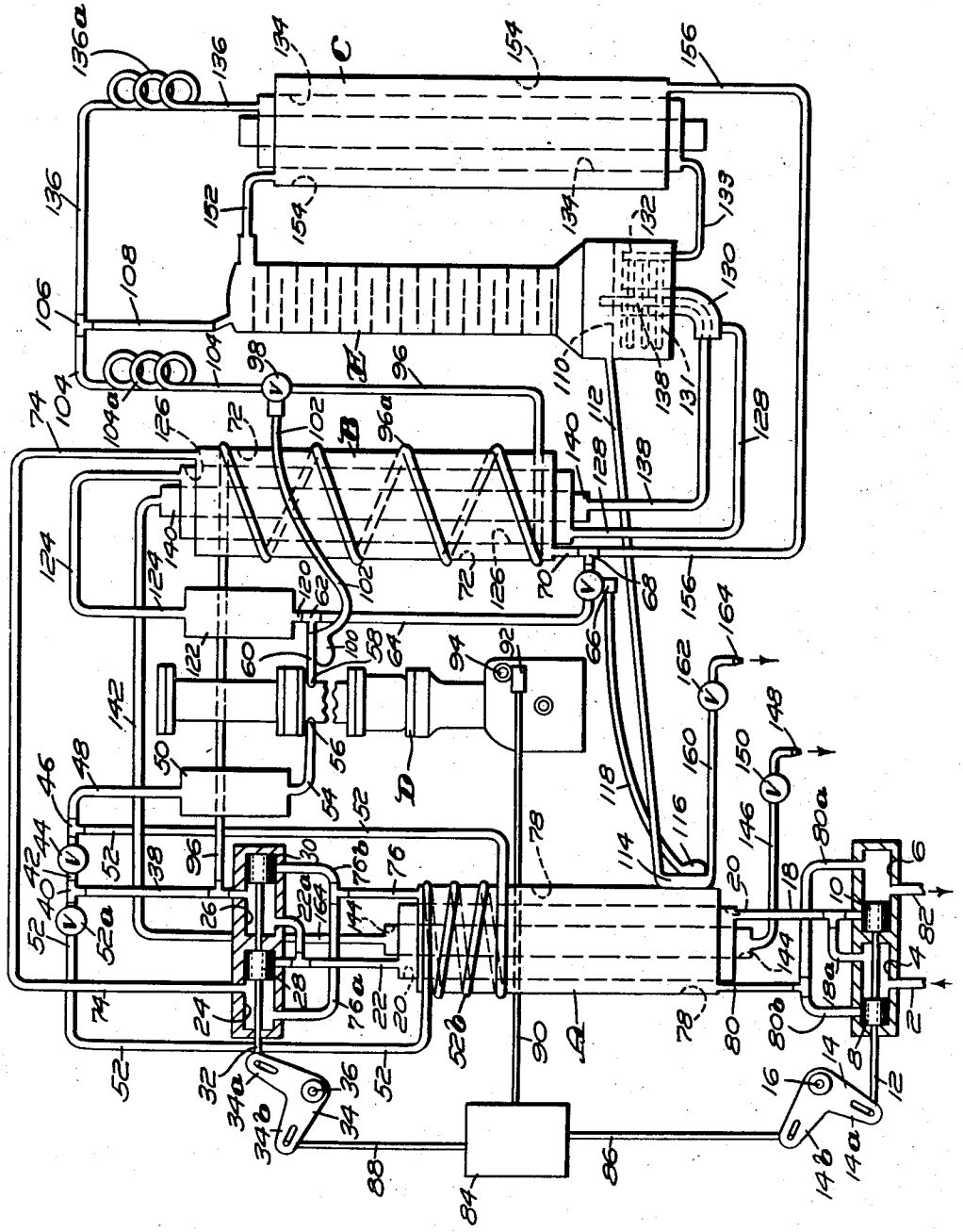
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CONTROL FOR OXYGEN PRODUCING APPARATUS

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CONTROL FOR OXYGEN PRODUCING APPARATUS

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13 Claims. (Cl. 62—2)

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This invention relates to controls for oxygen producing apparatus.

The object of this invention is to provide for the automatic control of the method and apparatus of the character disclosed in a copending application, Serial No. 661,253, filed April 11, 1946 by Samuel C. Collins. The present invention is particularly applicable to such apparatus when used for the production of substantially pure oxygen from atmospheric air, to the end that upon being started the performance will proceed through the cooling-down and liquefaction periods and bring about the normal operation to produce oxygen. It is a feature of the invention that should any inadvertent interruption occur in the oxygen producing operation, the controls will act automatically to repeat the starting-up cycles to restore the system to full operating conditions.

The best mode in which it has been contemplated to apply the principles of the present invention is shown in the accompanying diagrammatic layout of the preferred arrangement of apparatus but this drawing is to be deemed merely illustrative for it is intended that the patent shall cover by suitable expression in the appended claims whatever features of patentable novelty exist in the invention disclosed.

Referring to the drawing the preferred arrangement of oxygen producing apparatus comprises three heat exchangers, A, B and C, an expander D, a fractionating column E, numerous connections, and the several control devices which render the performance of the apparatus entirely automatic throughout what may be termed three rather distinct periods of the overall operation. These periods may be designated as the cooling-down period during which the various parts of the apparatus are cooled to temperatures suitable for their proper operation, the liquefaction period during which a sufficient charge of liquefied constituents of air is produced to affect certain controls, and the distillation period during which the desired oxygen is generated. The first two periods are transitory, each lasting about an hour, but the distillation period is not one of any special duration for it may go on indefinitely so long as the apparatus is supplied with compressed air.

The cooling-down period

This period is solely a preliminary one and its purpose is to cool down the apparatus as a whole. For clarity of disclosure the various elements of the apparatus are shown in the drawing in a sort of distributed arrangement, but in the actual apparatus the elements are closely adjacent one another within an overall casing. Spaces between the elements and between them and the casing are packed with good heat insulating material such as glass wool. To cool down the apparatus compressed air need be passed through only one of the heat exchangers on its way to and from the expansion engine, since in such a limited cycle of flow the expansion of the air with the performance of external work would produce the desired cooling-down effect. However, since in the subsequent liquefaction period it is necessary to produce a charge of the liquefied constituents of the air, we prefer a course of flow of the air which will serve the functions of both periods.

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Accordingly during the cooling down period the air flows through the heat exchangers A and B and the expander D. Compressed air, preferably at from 150 to 175 pounds per square inch (p. s. i.) and at ordinary room temperatures, is brought to an air inlet 2 of the apparatus. This inlet leads to one chamber 4 of a pair of valve chambers 4 and 6 in each of which is a valve, 8 and 10 respectively, secured to a common piston rod 12 which is connected to one arm 14*a* of a bell crank lever 14 pivoted at 16. When the valves 8 and 10 are in the positions shown the compressed air from inlet 2 passes through the chamber 4 into a branch 18*a* of a pipe 18 directly connected between the other chamber 6 and an inner annular passageway 20 of the exchanger A. The opening from chamber 6 into pipe 18 is closed by the valve 10 when positioned as shown.

The compressed air flows through the passageway 20 into a pipe 22 which, together with its branch 22*a*, leads to another pair of chambers 24 and 26 similar to those already described. These contain valves 28 and 30 respectively, having a common piston rod 32 which connects with one arm 34*a* of another bell crank 34 pivoted at 36. When the lower valves 8 and 10 are at the left ends of their respective chambers 4 and 6, the upper valves 28 and 30 are at the right ends of their respective chambers 24 and 26. Accordingly, as shown, the opening from pipe 22 to the chamber 24 is closed by the valve 28 while the opening from the branch 22*a* to chamber 26 is open, as is likewise an opening from this latter chamber into a pipe 38 leading to a T 40. The compressed air accordingly flows through pipe 22, branch 22*a*, chamber 26 and pipe 38 to the T 40.

From one side of this T 40 a pipe 42, containing a valve 44, connects with another T 46 from which a pipe 48 leads to a surge tank 50. From the other side of the T 40 a tube 52, containing a manually operated valve 52*a*, extends to the upper or colder end of the first heat exchanger A, forms a coil 52*b* thereabout and then runs to the T46. During the cooling-down period valve 44 is kept wide open and valve 52*a* is preferably closed so that the air flowing in pipe 38 to the

T 40 will flow past the valve 44 and T 46 on through pipe 48 to the surge tank 50. This tank is connected by a pipe 54 with the inlet 56 to the expander D. The details of this expansion engine are shown in a copending application, Serial No. 665,206, filed April 26, 1946, by Samuel C. Collins. Suffice it to say here that suitable valves and mechanism are provided which permit the compressed air at approximately its entering pressure of from 150 to 175 p. s. i. to be admitted through the inlet 56 to the cylinder of the engine, to expand therein against a movable piston and thereby perform external work, and to be discharged from an outlet 58 at about 5 p. s. i. and at a considerably reduced temperature, the reduction in temperature depending upon the expansion ratio, the efficiency of the engine and to some extent upon its temperature.

As before noted herein, the cooled air leaving the expander could return directly to the first heat exchanger, so far as the purposes of the cooling down period require, but we prefer to have this cooled air entering T 62 to flow thence along a pipe 64 which contains a pressure actuated control valve 66 and leads to a T 68. While the apparatus is cooling down this valve 66 remains open. From the T 68 the air flows through a pipe 70 into an outer annular passageway 72 through the second heat exchanger B. This passageway 72 is connected by a pipe 74 with the valve chamber 24.

With the valves 28 and 30 positioned as shown, the cooled air passes from the chamber 24 into one branch 76*a* of a pipe 76 leading to an outer annular passageway 78 through the first heat exchanger A. The other branch 76*b* of this pipe 76 is connected to the other valve chamber 26 but its opening thereinto is closed by valve 30 as shown. The cooled air accordingly passes through the annular passageway 78 in the first heat exchanger and thence through a pipe 80 and its branch 80*a* to the valve chamber 6, whence it is discharged from the apparatus through an outlet 82. Another branch 80*b* from the pipe 80 leads to the other valve chamber 4 but flow of the cooled air into this chamber is prevented by the valve 8.

Periodically (about every two minutes) the switch valves 8, 10, 28, and 30 are shifted in their respective chambers by the action of suitable reversing mechanism indicated by the rectangle 84. This is connected by a rod 86 with the arm 14*b* of the bell crank 14 and by another rod 88 with the arm 34*b* of the bell crank 34. The reversing mechanism is driven by a shaft 90 having a worm and gear connection 92 with a shaft 94 of the expander D. The purpose of this periodic shifting of the switch valves has to do with the cleaning of the annular passageways through the first heat exchanger A and the purification of the air prior to its entry into the expander D, of which more will be said later herein.

During the cooling-down period the entering compressed air is cooled, first by an exchange of heat with the cooled air flowing in the opposite direction through the first heat exchanger A and then further cooled by expansion with the performance of external work through the agency of the expander D. This cooling proceeds with continuing fall of temperature throughout the whole apparatus for about an hour or an hour and a quarter. By that time the air leaving the expander D and passing through the pipe 64 has reached a temperature of approximately 103° K. or —274° F. and initiates the liquefaction period.

The liquefaction period

During this period the second heat exchanger B acts as a liquefier to produce a charge of liquefied air in the base of the fractionating column E. The air to be thus liquefied is taken from the pipe 38 just beyond the first heat exchanger A. A tube 96 leading from pipe 38 forms a coil 96*a* or passageway about the heat exchanger B in good thermal contact therewith and then runs to another pressure actuated valve 98 which is responsive to the temperature conditions of the exhaust fluid from the expansion engine. This valve 98 is closed during the cooling down period and normally remains closed after the apparatus enters upon its oxygen producing performance. Despite its being closed the high pressure air from pipe 38 stands in the passageway 96*a*, and when the temperature of the air passing through the outer annular passageway 72 of the second heat exchanger B has reached approximately 103° K. or —274° F. the air in the coil 96*a* becomes liquefied.

In close thermal contact with the pipe 60, leading from the discharge port 58 of the expander, is a bulb 100 containing an expansible fluid. This bulb is connected by a tube 102 with the pressure-responsive means of the valve 98. When the air in the coil 96*a* becomes liquefied the temperature of the air being discharged from the engine will be such as to cool the fluid in bulb 100 to a point where its pressure permits valve 98 to open. This permits the high pressure air in pipe 38 and tube 96 to force the liquid air in the coil 96*a* past the now open valve 98 into a tube 104. This tube has a restriction winding 104*a* therein and runs from valve 98 to a T 106. The latter is connected by a pipe 108 with the top of the rectifying column E, the preferred details of which are disclosed in a copending application, Serial No. 676,075, filed June 11, 1946, by Howard O. McMahon. As the liquid air from coil 96*a* moves on as just described, more is formed in the coil 96*a* and in turn passes along to the column E. If this flow through tube 104 tends to become so rapid that gaseous air passes along with the liquid air the bubbles carried into the restriction winding 104*a* impede the flow and enable the desired liquefaction of the air in coil 96*a* to be accomplished.

In due time, usually in about an hour after the liquid air begins to be formed in coil 96*a*, the collection of this liquid air in the base of the column E reaches a level, indicated by the dotted line 110, at which it can run into a tube 112 leading from the boiler of the rectifier E to a vaporizing chamber 114. This chamber should be located where the temperature which affects it externally is such that upon liquid entering the chamber it is vaporized and returned through tube 112 to the fractionating column. For example, the chamber might be located outside the casing of the apparatus but for convenience it is preferred to place it in thermal contact with the heat exchanger A as shown. Closely associated with the chamber 114 is a bulb 116 which is connected by a tube 118 with the pressure responsive means of the valve 66. This bulb contains an expansible fluid whose pressure varies with its temperature. As the liquid from the base of the fractionating column flows through tube 112 into the chamber 114, the temperature of the wall of the chamber is greatly reduced despite the fact that vaporization of the liquid takes place. As a consequence the fluid in bulb 116 and tube 118 is cooled to a point where its pressure permits valve 66 to close

and cut off the flow of the expander air from the engine D through the pipe 64.

This forces the air leaving the expander to flow through pipe 60 to T 62 and thence through a pipe 120 into a surge tank 122. The air passes thence through a pipe 124 into an inner annular passageway 126 through the second exchanger B, whence it then proceeds by a pipe 128 to a central manifold 130 forming part of the boiler of the fractionating column E. The details of a preferred form of boiler are disclosed in an application for patent, Serial No. 674,521, filed June 5, 1946, now Patent Number 2,494,304, dated January 10, 1950, by Howard O. McMahon. The central inlet manifold 130 is connected by a coil of tubes 131 with an outlet manifold 132 which in turn is connected by a pipe 133 with an inner annular passageway 134 through the third heat exchanger C. The air in passing through the coil 131 gives up heat to the liquid outside the coil in the boiler and is itself liquefied during this heat exchange action. The liquid air passes on through pipe 133, passageway 134 wherein it is further cooled, and flows thence into a tube 136. The latter contains an expansion device, here represented as a capillary restrictor 136a, and continues on to the T 106. The liquid air is expanded in its passage through the restrictor 136a, and moves on at reduced pressure to the T 106 and thence through the tube 108 to be distributed in the top of the fractionating column E, wherein the fractionation and distillation of the air takes place.

The resistance to flow offered by the restrictor 136a is such that it causes the air leaving the expander D through the pipe 60 to assume a pressure of about 70 p. s. i. and a temperature of about 108° K. or —265° F. When this temperature is communicated to the fluid in bulb 100 and tube 102 it effects the closure of valve 98. This stops the flow of air from pipe 38 through the tube 96 and coil 96a and thus causes all flow of air to be through the expander D, the second heat exchanger B, the coil of tubes 131 in the boiler of the fractionating column, and the third heat exchanger C into the top of the column E. This brings the apparatus to full operative setting for the production of oxygen. As noted, all the air is expanded in the engine D with the performance of external work, is liquefied in the boiler coil, and is distributed at reduced pressure into the top of the column E for distillation.

The distillation period

The liquid air trickling down through the packing of the column in counter-flow with vapors rising in the column is separated into its constituents. The nitrogen, argon and such other constituents as may be "boiled-off" rise to the top of the column while the oxygen passes down as liquid to the bottom about the coils, gradually displacing the liquid air which was collected there during the liquefaction period. This air is vaporized and passes upward through the column with some resulting rectification. In due time the space of the column about the coil 131 becomes filled with liquid which is for the most part oxygen with some nitrogen, argon and perhaps other ingredients present. The latter elements are substantially all eliminated within the boiler proper so that eventually substantially pure oxygen gas enters a tube 138 extending upward within the central manifold 130. This oxygen gas flows through the tube 138 into a central passageway 140 through the second heat exchanger B and continues on through a pipe 142 to a central passageway 144 in the first heat exchanger A, whence it moves on through pipe 146 to an outlet 148 from which the discharge is controlled by a valve 150.

The nitrogen, argon and such other vapors as make up the effluent rise in the column E and pass out of the top of the column E through a pipe 152 that leads to an outer annular passageway 154 through the third heat exchanger C. The effluent then flows along a pipe 156 to the T 68 and thence through pipe 70 into the annular passageway 72 through the second heat exchanger B. From this passageway the effluent moves along pipe 74 to valve chamber 24. With the switch valves in the positions shown the effluent moves on through the branch 76a and pipe 76 into the annular passageway 78 through the first heat exchanger A and then goes through pipe 80 and branch 80a into chamber 6 whence it escapes from the system through the discharge outlet 82. In all three heat exchangers the direction of flow of the effluent is counter to that of the air stream and in each exchanger heat is taken from the air and absorbed by the effluent. In exchangers B and A, the counter-flowing stream of oxygen in the central passageways also absorbs some heat from the air.

As earlier noted, once the operation of the apparatus is started the switch valves 8, 10, 28 and 30 are shifted periodically. The flow of air and of the effluent when the valves are in the positions shown has already been described. When the several valves are shifted to the opposite ends of their respective chambers, the entering air will flow from inlet 2 through chamber 4 into branch 80b and thence through pipe 80 into the outer annular passageway 78 through the heat exchanger A, going on through pipe 76 and branch 76b into chamber 26 from which it passes on to the expander. At the same time the effluent from pipe 74 enters chamber 24 and flows into pipe 22 and thence through the inner annular passageway 20 of the first heat exchanger. It goes on through pipe 18 into chamber 6 to be discharged through the outlet 82.

During the flow of air through the first heat exchanger, water vapor and carbon dioxide, and possibly other impurities, are deposited on the wall of the passageway and would in time either clog the passageway or adversely affect its flow capacity. By changing the air flow from one annular passageway to the other at frequent intervals these deposits are kept small while forming and then are entirely removed as the effluent is counter-flowed through the passageway. This reevaporates, sublimes or otherwise removes the water vapor and carbon dioxide and other impurities and all are carried out with the effluent through the discharge outlet 82.

In some instances it may occur that the conditions of pressure and temperature which naturally arise in a heat exchanger are not favorable for the complete removal of the deposits. In such cases either the pressure or temperature should be artificially adjusted. One way of doing this is to compress the air to a higher pressure so that the deposits of carbon dioxide form at a higher temperature. Another way is to recirculate a portion of the compressed air about that region of the first heat exchanger at which the carbon dioxide deposits occur, after the compressed air has emerged from that heat exchanger and before it has gone to the expansion engine. For example, with valve 52a opened, the

valve 44 may be set so that a desired portion of the compressed air flowing from the first heat exchanger is caused to pass through the tube 52 and coil 52b to rejoin the remainder of the air passing through the valve 44. This cooled compressed air flowing in the coil 52b cools the region of the heat exchanger where the carbon dioxide would normally be deposited and causes the deposit to take place nearer to the warmer end of the exchanger where the evaporative capacity of the returning waste gases is amply sufficient to remove the deposits. In case the functions of coil 52b are not deemed necessary the valve 52a may be closed, thus causing all the air from the first exchanger to flow directly to the T46.

If low pressure liquid oxygen is desired it may be withdrawn from the chamber 114 through a pipe 160, valve 162 and outlet 164.

Ordinarily the distillation or oxygen producing period will continue as long as the apparatus is supplied with compressed air. The liquid in the base of the column will not rise above the level 110 desired, because at this level it will flow into tube 112 and chamber 114 and, unless drawn off from this chamber, will be vaporized, the vapor returning through the tube 112 into the column. If for any reason the liquid should inadvertently fall below the level 110, the liquefied constituents of air in the tube 112 and chamber 114 will be entirely vaporized very promptly. This will permit the temperature of bulb 116 to rise due to the heat transfer from the first heat exchanger A, causing the fluid therein and in tube 118 to expand and bring about the opening of valve 66. Air will thereupon again flow through pipe 64 to T 68, join the effluent in pipe 156 and move on through pipe 70 into heat exchanger B. This will promptly reduce the temperature of pipe 60 and so affect the fluid in bulb 100 and tube 102 that valve 98 will open to permit liquid air from the passageway 96a about the second heat exchanger B to pass on into the column and restore the liquid level in the base to that desired. Upon reaching the level 110 and overflowing into chamber 114 the valve 66 is again closed, and the closure of valve 98 will promptly follow thus automatically restoring the oxygen producing operation of the apparatus. Accordingly, once the distillation period is brought about the controls will maintain the operation of the apparatus for the production of oxygen, even restoring this operative condition if for any reason not anticipated the yield of liquid in the base of the column should be unexpectedly reduced.

After the apparatus is in full operation the pressure of the incoming air may be lowered if desired, and even with a pressure as low as 100 p. s. i. the oxygen will continue to be produced. It is felt, however, that somewhat more efficient operation takes place when the compressed air is supplied at a pressure somewhere in the neighborhood of 125 p. s. i. If 100 cubic feet of compressed air at about this pressure and at room temperature is put into the apparatus, then from 10 to 20 cubic feet of substantially pure oxygen gas (99.6% O_2) will be delivered from outlet 148 at approximately room temperature and a pressure of about 5 p. s. i. Under the same conditions of entering air, the apparatus will produce about 2 kilograms of liquid oxygen (which would be about 5 cubic feet if the oxygen were vaporized) which can be withdrawn from outlet 164 at substantially atmospheric pressure.

We claim:

1. Apparatus for liquefying and separating compressed mixed gases, comprising a heat exchanger wherein said mixed gases are passed in heat exchange relation with a cold fluid, an expansion engine connected to said heat exchanger to receive and expand the mixed gases, fractionating means connected to the exhaust of said engine to receive the expanded mixed gases, conduit means leading from said fractionating means to said heat exchanger to provide said cold fluid thereto, a bypass leading from said exhaust of said engine to said conduit means whereby said expanded mixed gases flow to and through said heat exchanger in heat exchange relation with said mixed gases, and a thermally actuated control valve in said bypass actuated by liquid formed in said fractionating means, whereby said valve is actuated into closed position by the temperature of said liquid to permit all of said expanded mixed gases to flow into said fractionating means.

2. The apparatus of claim 1, wherein the heat exchanger is a recuperative reversing exchanger provided with valve means operative to alternate periodically the flows of the compressed mixed gases and the cold fluid between two passageways in said exchanger.

3. Oxygen producing apparatus comprising a heat exchanger having passageways for separated flows of fluid one of said passageways being for the introduction of compressed air, an expansion engine connected to the outlet end of said incoming air passageway, fractionating and distilling means into which said engine discharges, conduit means leading from said fractionating and distilling means to a second passageway of said heat exchanger, a bypass leading from the exhaust end of said engine to said conduit means whereby flow of fluid from the engine passes through the bypass to the heat exchanger to flow therethrough in said second passageway to effect cooling of the incoming compressed air in the first passageway, and a thermally actuated control valve in said bypass actuated by liquefied constituents of air in said fractionating and distilling means whereby said valve is actuated into closed position by the temperature of said liquefied constituents to permit all of the air flowing from the engine to pass into the fractionating and distilling means; said valve being actuated into open position by said temperature when said temperature is appreciably above that of the normal boiling point of said liquefied constituents.

4. Oxygen producing apparatus comprising a heat exchanger having passageways for separated flows of fluid one of said passageways being for the introduction of compressed air, an expansion engine connected to the outlet end of said incoming air passageway, fractionating and distilling means into which said engine discharges, conduit means leading from said fractionating and distilling means to a second passageway of said heat exchanger, a bypass leading from the exhaust end of said engine to said conduit means whereby flow of fluid from the engine passes through the bypass to the heat exchanger to flow therethrough in said second passageway to effect cooling of the incoming compressed air in the first passageway, and a thermally actuated control valve in said bypass actuated by liquefied constituents of air in said fractionating and distilling means whereby said valve is actuated into closed position by the temperature of said liquefied constituents to permit all of the air flowing from the engine to pass into the fractionating and distilling means; said valve being actuated into open position by said temperature

when said temperature is appreciably above that of the normal boiling point of said liquefied constituents, and being actuated into closed position by the effect of said temperature when said temperature is appreciably lower.

5. Oxygen producing apparatus comprising a first heat exchanger having separate thermally bonded passageways in heat exchanging relation one of said passageways being for the introduction of compressed air, an expansion engine having its inlet connected to the outlet end of said incoming air passageway, a second heat exchanger having separated thermally bonded passageways in heat exchange relation, one of which passageways is connected with the outlet from said engine and another of which passageways is connected with the inlet of said expansion engine and with a fractionating column beyond said second exchanger, and a thermally actuated valve in the latter passageway responsive to the temperature conditions of the exhaust fluid of said engine; the said valve being opened by the effect of the temperature of said exhaust fluid when said temperature reaches a degree wherein the air in said latter passageway becomes liquid, to permit flow of said liquid air to said column.

6. Oxygen producing apparatus comprising a heat exchanger having passageways for separated flows of fluid one of said passageways being for the introduction of compressed air, an expansion engine connected to the outlet end of said incoming air passageway, a second heat exchanger also having passageways for separated flows of fluid, the first passageway of said second heat exchanger being connected to the discharge side of said expansion engine, fractionating and distilling means into which said engine discharges during normal operation of the apparatus, and a second passageway of said second heat exchanger being connected to a second passageway of said first heat exchanger, a by-pass extending from the connection between the expansion engine and the second heat exchanger to the second passageway in the second heat exchanger, whereby flow of fluid from the engine passes through the second heat exchanger and returns to the first heat exchanger to flow therethrough in one passageway to effect cooling of the incoming compressed air in the other passageway, and a thermally actuated control valve in said by-pass responsive to the temperature in the region of the first heat exchanger; said valve being held open by a temperature not substantially different from that of said region to permit the air flowing from the engine to pass through the second heat exchanger and return to the first heat exchanger.

7. Oxygen producing apparatus comprising a heat exchanger having passageways for separated flows of fluid one of said passageways being for the introduction of compressed air, an expansion engine connected to the outlet end of said incoming air passageway, a second heat exchanger also having passageways for separated flows of fluid, the first passageway of said second heat exchanger being connected to the discharge side of said expansion engine, fractionating and distilling means into which said engine discharges during normal operation of the apparatus, and a second passageway of said second heat exchanger being connected to a second passageway of said first heat exchanger, a by-pass extending from the connection between the expansion engine and the second heat exchanger to the second passageway in the second heat exchanger, whereby flow of fluid from the engine passes through the second heat exchanger and returns to the first heat exchanger to flow therethrough in one passageway to effect cooling of the incoming compressed air in the other passageway, and a thermally actuated control valve in said by-pass responsive to an excess of liquefied constituents of air in said fractionating and distilling means whereby said valve closes when the level of said liquefied constituents reaches a predetermined point to permit all of the air flowing from the engine to pass into the fractionating and distilling means.

8. Oxygen producing apparatus comprising a first heat exchanger having separate thermally bonded passageways in heat exchanging relation one of said passageways being for the introduction of compressed air, an expansion engine having its inlet connected to the outlet end of said incoming air passageway, a second heat exchanger having separated thermally bonded passageways in heat exchanging relation, one of which passageways is connected with the outlet from said engine and a second of which passageways is connected with a second passageway of the first exchanger, a by-pass leading from the connection between the outlet of said engine and the second heat exchanger to the said second passageway of the second exchanger whereby the incoming air after passing through the first heat exchanger and engine is returned through the second exchanger to the first exchanger and discharged therefrom, a fractionating column beyond said second exchanger, conduit means extending from the connection between the first exchanger and expansion engine to the top of said column including a third passageway in said second heat exchanger, and a thermally actuated valve in said conduit means responsive to the temperature conditions of the exhaust fluid of said engine; the said valve being opened when the temperature of said exhaust fluid reaches a degree whereat the air in said third passageway becomes liquid, to permit flow of said liquid air to said column.

9. Oxygen producing apparatus comprising a first heat exchanger having separate thermally bonded passageways in heat exchanging relation one of said passageways being for the introduction of compressed air, an expansion engine having its inlet connected with the outlet end of said incoming air passageway, a second heat exchanger having separated thermally bonded passageways in heat exchanging relation with one of its passageways connected with the outlet of said engine and a second of its passageways connected with a second passageway of the first exchanger, a by-pass leading from the connection between the engine and the second exchanger to the said second passageway through the second exchanger, a thermally actuated valve in said by-pass, a fractionating column having a boiler and a coil therein connected with the first said passageway of the second exchanger, a conduit leading from the connection between the first heat exchanger and the engine to the top of the fractionating column including a third passageway in the second exchanger, a thermally actuated valve in said conduit and responsive to the temperature of the exhaust fluid of said engine and adapted to be opened when the temperature of said exhaust fluid is such that liquid air forms in the said third passageway whereupon the said liquid air flows to the top

of the fractionating column and accumulates in the boiler thereof, and means for conducting said liquefied product from the boiler, upon its reaching a predetermined level therein, to effect a temperature condition which actuates the valve in the by-pass whereby said valve in the bypass is closed to cause the air leaving the engine to flow through the second exchanger to a coil in the boiler of the fractionating column, the resulting increase of temperature of the exhaust fluid of the engine effecting closure of the said valve in the conduit, a connection between said boiler coil and the top of the column whereby the liquid air formed in said boiler coil flows to the top of the column, and a connection from the top of said column to the second exchanger for flow of effluent from the column through the second exchanger and thence through the first exchanger.

10. Oxygen producing apparatus comprising a first heat exchanger, an expansion engine, a second heat exchanger and a fractionating column having a coil at its base, connected in series with one another, whereby compressed air introduced to the first heat exchanger flows therethrough and through the engine and second exchanger to said coil wherein the air is liquefied, a connection from said coil to the top of the column including an expansion device whereby said liquid air at reduced pressure is admitted to the column for rectification resulting in the accumulation of fractionated liquefied product in the base of said column about said coil, means for maintaining a predetermined level of said liquefied product comprising a conduit having its opening from said column at the said level and having its end remote from said column in thermal relation to the first heat exchanger so that if the accumulation of liquefied product tends to exceed said level the excess of liquefied product flows in said conduit to the end adjacent said first heat exchanger to be there vaporized and returned through said conduit to the column in gaseous form.

11. Oxygen producing apparatus comprising a heat exchanger to which compressed air is introduced and a fractionating column wherein said air is rectified to provide an accumulation of fractionated liquefied product in the base of said column, and means preventing said accumulation beyond a predetermined level comprising a conduit connected to said base at the said level and extending to a region adjacent the first heat exchanger whereat heat from the exchanger will vaporize said liquefied product flowing in said conduit from said base; the gaseous product thus formed returning to the column through said conduit in counterflow to the liquefied product therein.

12. Oxygen producing apparatus comprising a first heat exchanger having a passageway for inflow of compressed air and having another passageway in thermal relation to the air passageway for outflow of fluid, an expansion engine having its inlet connected with the outlet of said air passageway and having its outlet connected to a second heat exchanger, said second exchanger having three separate passageways in thermal relation with one another with one passageway having one end connected with the outlet of said engine and with a second passageway having its corresponding end connected with the outflow passageway of the first exchanger and having its opposite end connected with the outlet of the engine, a thermally actu-

ated valve in the last said connection, said valve being adapted to remain open during any cooling-down period of the apparatus to permit the air to flow from said engine to the passageway of the second exchanger that is connected with the outflow passageway of the first exchanger, whereby the apparatus is cooled down by the flow of the air through the two heat exchangers and the expansion engine, a fractionating column, a conduit extending from the connection between the air passageway and the inlet to the engine through the third passageway and to the fractionating column, a thermally actuated valve in said conduit responsive to the temperature of the exhaust fluid flowing from said engine, the last said valve being opened upon the apparatus being cooled down sufficiently to effect liquefaction of the air in said third passageway, whereupon said liquefied air can flow into the said column.

13. Oxygen producing apparatus comprising a first heat exchanger having a passageway for inflow of compressed air and having another passageway in thermal relation to the air passageway for outflow of fluid, an expansion engine having its inlet connected with the outlet of said air passageway and having its outlet connected to a second heat exchanger, said second exchanger having separate passageways in thermal relation with one another with one passageway having its warm end connected with the outlet of said engine and with its opposite end connected with a coil in the base of a fractionating column, and with another passageway having its warm end connected with the outflow passageway of the first exchanger and having its opposite end connected with the outlet of the engine, a thermally actuated valve in the last said connection, the said valve being adapted to remain open during any cooling-down period of said apparatus to permit the air to flow from said engine to the passageway of the second exchanger that is connected with the outflow passageway of the first exchanger, whereby the apparatus is cooled down by the flow of the air through the two heat exchangers and the expansion engine, and being actuated to closed position by the action of the temperature of the liquefied constituents of air accumulating in the base of the fractionating column during continued operation of the apparatus.

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HOWARD O. McMAHON.

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2,113,680	De Baufre	Apr. 12, 1938
2,460,859	Trumpler	Feb. 8, 1949
2,280,383	De Baufre	Apr. 21, 1942

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