Aug. 16, 1955 W. W. PAGET 2,715,316

OXYGEN GENERATING APPARATUS

Filed Nov. 5, 1952 3 Sheets-Sheet 1

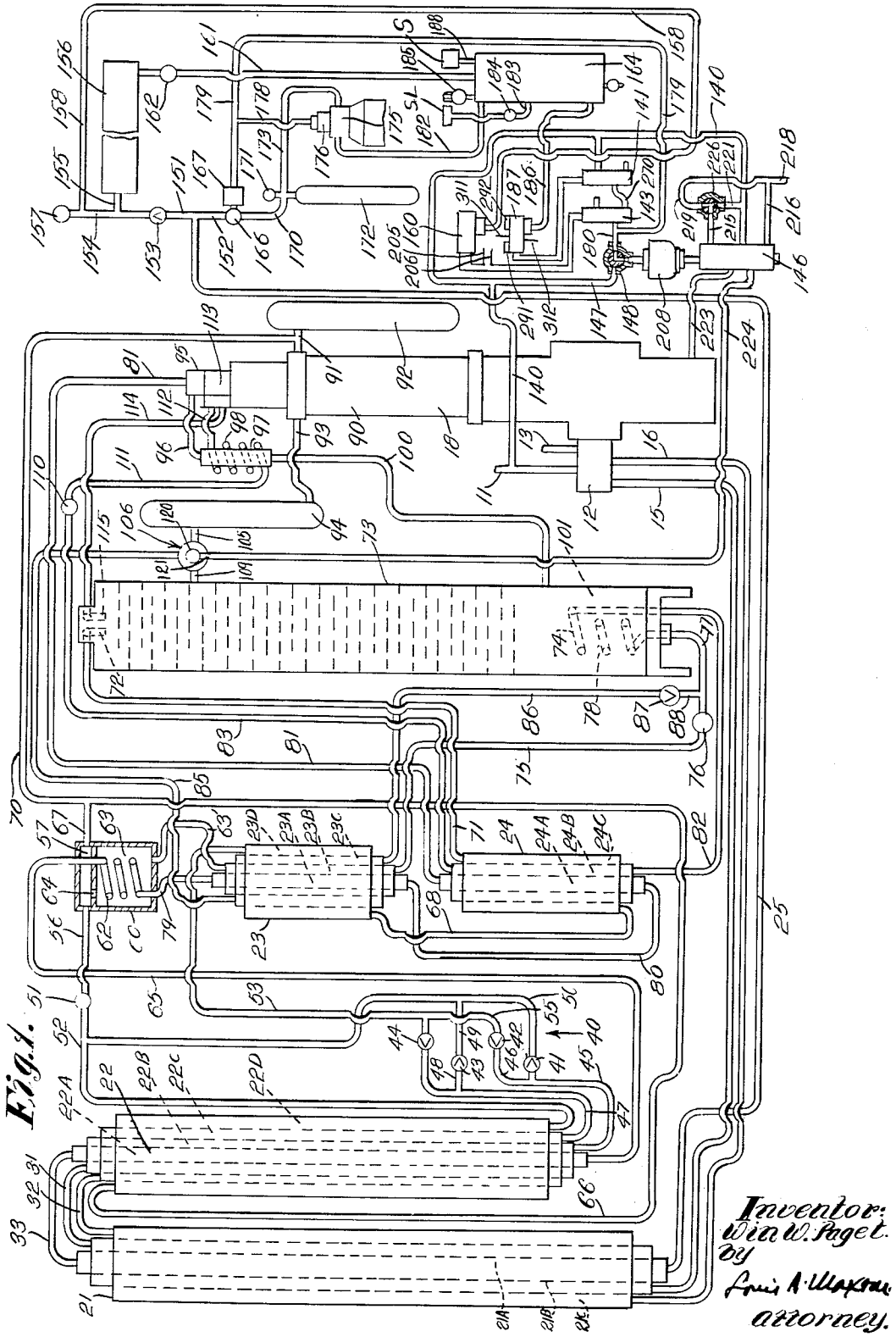

Fig. 1.

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OXYGEN GENERATING APPARATUS

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Fig. 4.

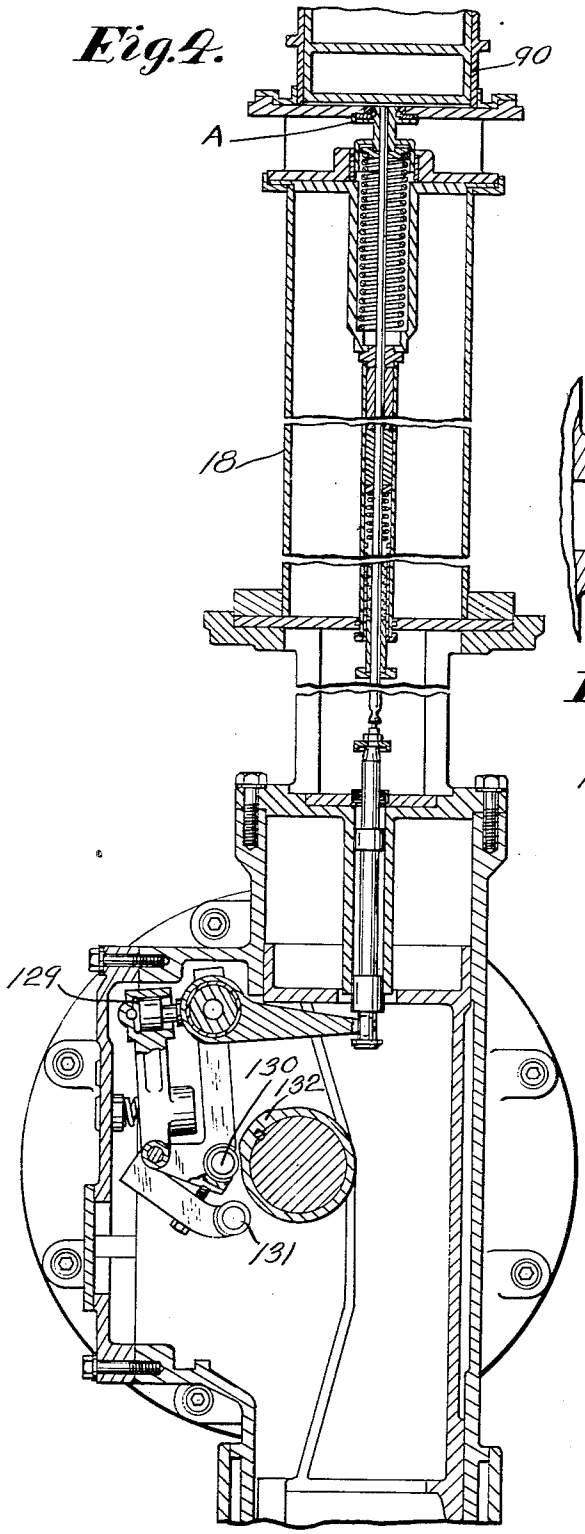


Fig. 2.

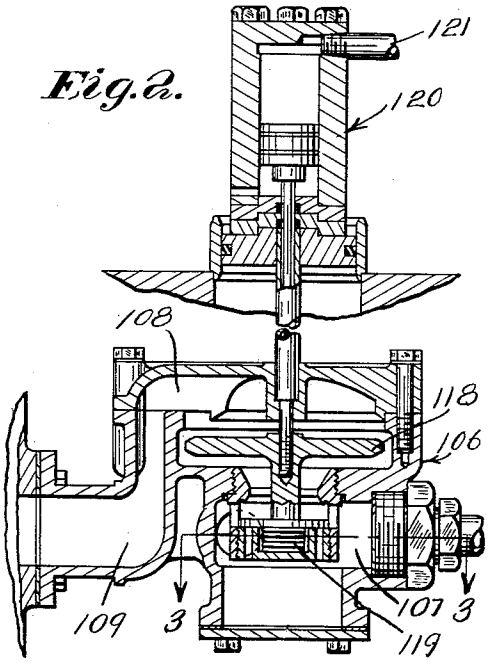
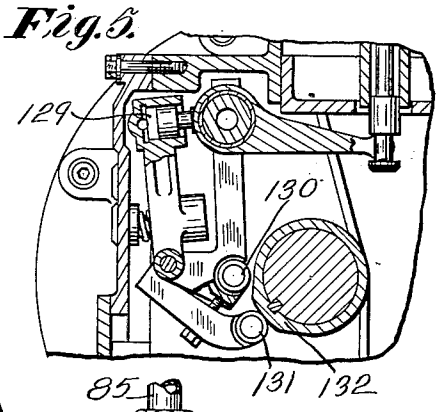


Fig. 5.



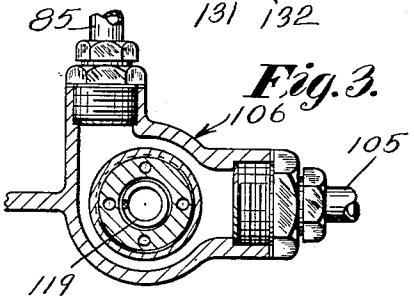


Fig. 3.

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OXYGEN GENERATING APPARATUS

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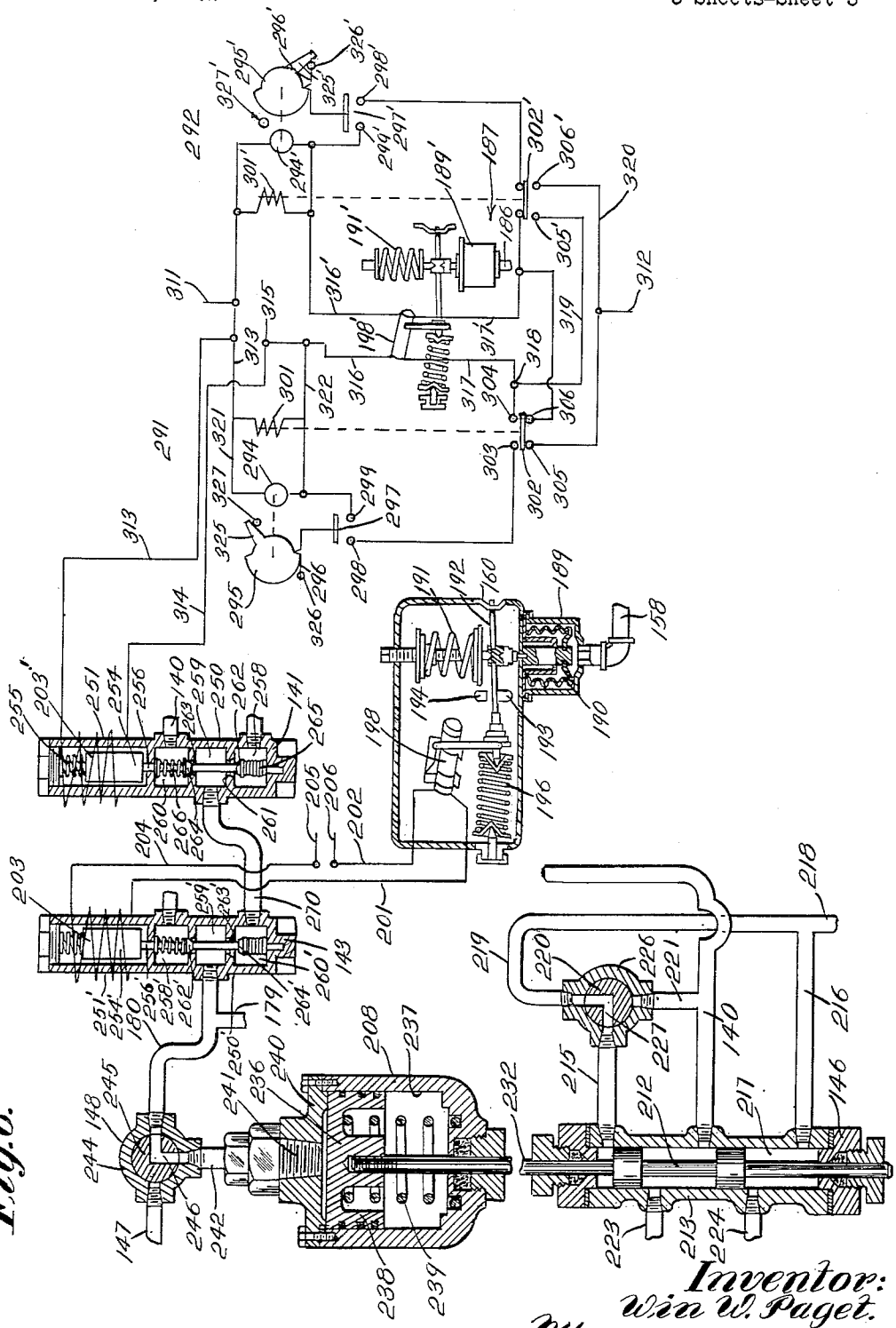

Fig. 6.

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United States Patent Office 2,715,316 Patented Aug. 16, 1955

2,715,316

OXYGEN GENERATING APPARATUS

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Application November 5, 1952, Serial No. 318,801

20 Claims. (Cl. 62—2)

This invention relates to apparatus for providing oxygen or other gases to meet variable demands. It wil be described with particular reference to oxygen, but will be understood not to be so limited.

An essentially self-regulating apparatus for freeing compressed air from solidifiable impurities such as water vapor and carbon dioxide, for making available from the purified compressed air, by a method and apparatus employing refrigeration and rectification, oxygen with a purity of 99.5% or better, and for delivering the oxygen at a relatively low pressure, as on the order of 50 p. s. i. g., or at a much higher pressure on the order of 2000 p. s. i. g., is disclosed in the Win W. Paget Patent No. 2,588,656. See also the patent to Collins and Paget, No. 2,601,764.

Such an apparatus may advantageously be used alternatively as a source of oxygen for a shop line, at which time some boosting of the relatively low delivery pressure of 50 p. s. i. g. will be desirable, or as a source of high pressure oxygen for use in cylinder charging or storage in a space of relatively small volume but considerable capacity for feedback at reduced pressure, when needed, for use in the shop line, the generator being maintained in operation except when the oxygen made available so far exceeds the rate of use and the storage capacity as to make a shut-down necessary, and the shiftings between low and high pressure production being automatically controlled.

In such a system, in a preferred form, oxygen discharged at the relatively low pressure, for example on the order of 50 p. s. i. g., will not enter the high pressure storage system, because of the presence of a check valve in the line leading to the latter requiring a minimum pressure, perhaps 120 p. s. i. g., to open it. It will desirably pass through a pressure fluid operable shutoff valve to a booster which is adapted to boost the pressure of the oxygen received at on the order of 50 p. s. i. g., in the particular case mentioned, to on the order of 200 p. s. i. g. and to deliver the oxygen at the boosted pressure to a receiver which is adapted to feed oxygen, desirably through a fixed-downstream-pressure-type of pressure reducing valve, at say 115 p. s. i. g. to a shop line. Desirably the booster will be provided with suitable unloading means, also pressure fluid operable; and means will be provided for automatically effecting unloading of the booster and closing of said shutoff valve when the generator is switched automatically to discharge at high pressure, the operating fluid desirably being compressed air at say on the order of 160 p. s. i. g., taken from the supply to the oxygen generator for processing therein.

Desirably the pressure in the receiver to which the booster discharges may be employed as the control, not only for the unloading means for the booster and for the shutoff valve, but also for automatic apparatus for effecting the necessary changes to convert the generator from low pressure to high pressure oxygen delivery and vice versa.

As it is undesirable to permit switchings from low to high pressure operations and vice versa at short intervals, there is desirably included appropriate means, as, for example, time delay switch means for preventing variations in pressure in the booster receiver, should they occur so as to cause opposite controls of the pressure responsive switch to take place too close to each other, from causing switching of the generator from low to high pressure operation or vice versa until after a predetermined period of operation according to whichever mode is in effect.

Desirably means is included for supply of fluid through a suitable downstream-pressure-responsive, pressure-reducing valve for effecting the delivery of pressure from high pressure oxygen storage to the receiver which is connected with the shop line, if the pressure in the latter falls to some value near the shop line pressure.

The high pressure storage system will desirably be provided with a safety valve set perhaps 100 pounds above the desired upper normal limit for high pressure oxygen storage, and there will be provided, under control of the pressure in the high pressure storage system, and set to operate at a value somewhat above the setting of the safety valve—so as to provide against possible failure of the latter to preclude further pressure build-up in such storage system—an overriding control for switching the generator to low pressure oxygen production and holding it in such mode of operation until the pressure in the high pressure storage system falls substantially below the upper desired limit.

An object of the invention is to provide an improved apparatus for providing gaseous oxygen, or some other gas, to meet variable demands. Another object of the invention is to provide an improved oxygen supply system, including an oxygen generating apparatus having provision for the delivery of oxygen at a relatively low pressure and at a much higher pressure, for supplying oxygen at a pressure intermediate said relatively low pressure and said relatively high pressure to a shop line or the like. A further object of the invention is to provide an improved oxygen supply system for a shop line or the like, including a provision for supplying oxygen at a relatively high pressure and at a relatively low pressure, and a booster for boosting the relatively low pressure to an intermediate pressure for use in shop lines, and including means responsive to variations in said intermediate pressure for controlling the admission of fluid to the booster, unloading the booster, and switching the generator from low to high pressure delivery, or vice versa. A further object of the invention is to provide an improved apparatus for the delivery of oxygen to a shop line at a relatively low pressure, or for the storage of oxygen at a relatively high pressure, and means controlled by the pressure in the high pressure storage system for effecting operation of the oxygen generator only according to its low pressure generating mode, in the event that the pressure in the high pressure storage apparatus exceeds a predetermined mtximum. A further object of the invention is to provide an improved apparatus including an oxygen generator adapted to provide oxygen at a plurality of relatively widely differing pressures, and having improved controlling means for effecting a switching of the generator from one production system to the other automatically, depending upon pressure variations in a reservoir from which oxygen may be delivered to a shop line, such generator having associated with it improved means for precluding switching from the provision of oxygen at one of said relatively widely differing pressures to the other, or vice versa, until operation has continued for a predetermined period regardless of the mode of operation. Another object is to provide an improved gas generator adapted to produce the gas it is intended to supply at two widely different pressures and to provide

therefor improved means for delivering the product gas to a shop supply line or to high pressure storage automatically, dependent upon pressure variations in a reservoir from which fluid is supplied at a constant downstream pressure to the shop line, and for the making available to the reservoir from the high pressure storage automatically of oxygen when the reservoir pressure falls to a value below which it is desired not to draw it down. Other objects and advantages of the invention will appear from this specification and the appended claims.

In the accompanying drawings, in which one illustrative embodiment of an oxygen supply system in which the invention is incorporated is shown,

Fig. 1 is a diagrammatic view showing the supply system.

Fig. 2 is a vertical sectional view through a bypass valve mechanism forming a part of the apparatus disclosed in Fig. 1.

Fig. 3 is a horizontal section through the bypass valve casing, on the plane of the line 3—3 of Fig. 2.

Fig. 4 is a somewhat diagrammatic view of an expansion engine admission valve control mechanism having improved cutoff changing mechanism.

Fig. 5 is a fragmentary view showing the position of the parts for longer periods of admission (later cutoff).

Fig. 6 is a somewhat diagrammatic view showing suitable controlling means for a by-pass valve and for a device for changing the point of cutoff of an expansion engine.

Because of the possibility of reference to Patent No. 2,588,656 and to Patent No. 2,601,764, it will be possible to provide a substantially less detailed description, than might otherwise be necessary, of the oxygen generator which is disclosed as a part of the present illustrative embodiment of the invention.

Referring first to Fig. 1 of the drawings, there will be observed an oxygen generator of the single column type—though it will be evident that a double column apparatus might equally well be employed—and it will be noted that an apparatus is disclosed including an expansion engine **18**; heat exchangers **21**, **22**, **23** and **24**; an evaporator-condenser **60**; a single column **73** having another evaporator-condenser **74** at its lower end, and a liquid oxygen pump **95**. Air is supplied at a suitable pressure, such as 160 p. s. i. g., through a supply connection **11**, as from a two-stage compressor with aftercooler and of a capacity substantially the same as the air processing capacity of the generating apparatus. The compressed air supply is adapted to be shifted by a suitable reversing valve device **12**, actuated at uniform intervals from the expansion engine, between conduits **15** and **16**, the one of these conduits which is not at any given time connected with the supply line **11** being connected to a vent line **13**. A suitable reversing valve mechanism may be noted in the application of Samuel C. Collins, Serial No. 661,253, filed April 11, 1946.

The heat exchanger **21** has three courses, all in good heat exchange relation with each other. These courses are designated **21A**, **21B** and **21C**.

Conduits **15** and **16** connect respectively to courses **21B** and **21C**, and these courses are in turn connected by conduits **31** and **32** with generally corresponding courses **22B** and **22C** of the heat exchanger **22**, which also has a course **22A** corresponding to the course **21A** of the heat exchanger **21**, and has a further, fourth, course **22D** to which further reference will be made later. A series of check valves are arranged beyond the heat exchanger **22** in the direction of flow toward the column **73**, these check valves being arranged to cooperate with the automatic reversing valve **12** in effecting reversal of flow of incoming air and outgoing effluent with respect to the B and C courses of the heat exchangers **22** and **21** and the conduits **15** and **16**. This reverse valve mechanism is generally designated **40** and includes four automatic check valves **41**, **42**, **43** and **44**. Such an arrangement is disclosed in the Collins application Serial No. 661,253 mentioned above.

A conduit **45** connects the lower end of course **22B** with the upstream side of check valve **41**, and a branch conduit **46** connects the conduit **45** with the downstream side of check valve **42**. The lower end of course **22C** is connected by a conduit **47** with the downstream side of the check valve **44**, and a branch **48** of the conduit **47** connects the conduit **47**, at a point between the course **22C** and the check valve **44**, with the upstream side of the check valve **43**. A conduit **49** connects the other (downstream) side of the check valve **43** with a conduit **50** which leads from the downstream side of the check valve **41** to a conduit **52** in which a restrictor device **51** is arranged and which connects the bottom of the previously mentioned course **22D** with the restrictor device **51**. This restrictor device creates a slight difference between the pressure in the conduit **52** and the pressure beyond the device **51**. A conduit **53** leads from the side of check valve **44** opposite the conduit **47**, that is from the upstream side of check valve **44**, to the outermost course of the heat exchanger **23**, that is, to course **23D** of the latter, and the upstream side of the check valve **42** is also connected with the conduit **53** by a conduit **55**. Nitrogen always flows outwardly through the conduit **53**. Each of the check valves **41**, **42**, **43** and **44** opens in the direction indicated by the point of the "V" marked thereon and prevents opposite flow. The courses **21A** and **22A** of the heat exchangers **21** and **22** are for leaving oxygen flow, and these are connected by a conduit **33**; and course **21A** is connected with an oxygen product line **25**. The restrictor **51** is connected by a conduit **56** to a chamber **57** within the top of the evaporator-condenser **60**.

Within the casing of the evaporator-condenser **60** there is an oxygen conducting course **62** connected by a conduit **65** with the lower end of the course **22A** of exchanger **22**. There is also a course **63** in close heat exchange relation with the course **62**, and the course **63**, which is connected at **64** with the chamber **57**, is a course for entering air.

The top of the course **22D** of the heat exchanger **22** is connected by a conduit **66** with a conduit **67** which leads from the chamber **57**, and the stream of air, consisting primarily of air from the conduit **67** and secondarily of air from the conduit **66** passes to a conduit **70** which leads to the intake of the expansion engine **18**, which is later more fully described.

The recirculation of a portion of the air which is passed through both of the heat exchangers **21** and **22**, through the course **22D** of the exchanger **22** serves to effect a complete separation of the water vapor and carbon dioxide out of the entering air stream. The duration of flow between switches of the incoming air and the outgoing nitrogen between the courses which they occupy alternatively may be on the order of three minutes.

When the air entering the system is caused to pass through the course **22B**, it flows past the check valve **41**. When the entering air is passing through the course **22C**, the course **22B** serves for the out-flow of nitrogen, which flows from the conduit **53** through conduit **55** and past check valve **42** and through conduits **46** and **45** to the course **22B**. When the course **22C** is serving for inflow of air, the entering air flows past the check valve **43**. When the course **22C** is conducting leaving nitrogen, the nitrogen flows past the check valve **44** and through the conduit **47**. As the entering air is at a much higher pressure than the leaving nitrogen, no check valve subjected on its discharge side to air can be opened by the lower nitrogen pressure. The heat exchanger **23**, previously mentioned, has four courses, all in good heat exchange relation to each other and severally designated **23A**, **23B**, **23C** and, previously referred to, **23D**. The heat exchanger **24** as shown has three courses, all in good heat exchange relation to each other and severally desig-

nated 24A, 24B and 24C. As above noted, the conduit 53 is connected with the course 23D of exchanger 23 at the top of the latter. The lower end of course 23D is connected by conduit 68 with the bottom of the course 24C of the exchanger 24, while the top of the course 24C is connected by a conduit 71 with the nitrogen outlet (the efflux connection) 72 of the single column 73. Compressed air course 63 of the evaporator-condenser 60 is connected by a conduit 63' with the top of course 23B of the exchanger 23. The bottom of that course is connected by conduit 75 to a suitable pressure reducing valve device 76 which is adapted, in the oxygen generator being described for illustration, during oxygen production, to effect a pressure drop through it on the order of 88 p. s. i. This is substantially the same reduction as occurs in the expansion engine 18 when the latter is operating with late cutoff, as hereinafter explained. The downstream side of valve device 76 is connected by a conduit 77 with coil 78 of the evaporator-condenser 74 at the lower end of the column 73. Course 23A of exchanger 23 has its top connected with a conduit 79 leading to the oxygen course 62 of the evaporator-condenser 60, while its bottom is connected to the bottom of the course 24A of the exchanger 24 by a conduit 80. A conduit 81 leads from the top of course 24A and is connected with the discharge of the liquid oxygen pump 95 previously mentioned and later described. The evaporator-condenser coil 78 is connected at its other end, that is its end away from the conduit 77, by a conduit 82, with the course 24B of exchanger 24. The top of course 24B is connected with a conduit 83 as to which more will be said later. The course 23C of the heat exchanger 23 is connected at its top with an expanded air conduit 85, and its lower end is connected by a conduit 86 with a check valve 87 which is openable towards the conduit 77 and connected with the latter by a connection 88. The check valve 87 opens towards the conduit 77, but only when the pressure in the conduit 86 is sufficient to effect opening of the check valve 87 against the pressure in the conduit 77.

The expansion engine 18 is shown for purposes of illustration as of the character illustrated and described in the application of Win W. Padget, Serial No. 31,017, filed June 4, 1948, now Patent No. 2,678,028, granted May 11, 1954, and includes a cylinder 90 having admission and exhaust valves, the former shown at A in Fig. 4 and the latter not illustrated herein. Air under pressure is admitted to the admission valve from the conduit 70 through a conduit 91 with which an "in" surge tank 92 is connected so as to minimize fluctuations in flow. A discharge or exhaust connection 93 leads from the expansion engine to a "discharge" surge tank 94, which may have associated with it a strainer to catch any snow that might otherwise attain to the column while the heat exchangers 21 and 22 are not fully cooled down, during the starting of the apparatus. On the top of the expansion engine cylinder there is arranged the jacketed liquid oxygen pump 95, actuated herein by the expansion engine piston as shown in the Paget Patent No. 2,678,028. This pump 95 is adapted to raise the pressure of the liquid oxygen from around 7 p. s. i. g. to around 50 p. s. i. g. The conduit 81 is connected with the discharge of the liquid oxygen pump 95, and this pump has a suction connection 96 leading to it from a strainer 97 which is cooled or jacketed by liquid air in a jacket herein represented by a coil 98. The strainer 97 is connected by a conduit 100 with an evaporator-condenser chamber at the bottom of the column 73, the conduit 100 communicating with a chamber 101 formed in the bottom of the column and in which the coil 78 lies, at a point at the desired liquid level in the chamber. The "discharge" surge chamber 94 is connected by conduit 105 with a valve structure 106 which valve structure includes a passage or chamber 107 continuously in communication not only with the conduit 105 but also with the conduit 85, and another chamber 108 which is connectible with the chamber 107 under the control of a valve 118 later referred to again and which is connected through a conduit 109 directly with the interior of the column at a point spaced a suitable distance from the top of the latter. The valve structure 106 may properly be called a "by-pass" valve and it is adapted at appropriate times to connect the two chambers mentioned in communication with each other and thus to connect the "discharge" surge chamber 94 in free communication with the upper part of the column through the conduit 105, valve structure 106, and conduit 109.

The expansion engine 18 is shown provided with adjustable valve gear for permitting the engine to operate with admission for a relatively short portion of its working stroke, for example, 25%, or with admission for a considerably longer portion of its working stroke, for example 70%. When cutoff is relatively late in the working stroke, the valve structure 106 will, through means to be later described, be caused normally to prevent communication between the "discharge" surge chamber 94 and the column through the conduit 109, and when communication between the "discharge" surge chamber 94 and the column is effected by appropriate adjustment of the valve 118, the expansion engine will be operated with admission for the relatively short portion of its working stroke. In the Collins and Paget Patent No. 2,601,764, certain considerations affecting the selection of point of cutoff are discussed, but these need not be gone into here.

While various arrangement for effecting the desired change in the period of admission may be employed (see the Collins and Paget patent last-mentioned) it will suffice for this case very briefly to describe a preferred arrangement disclosed in the Paget Patent No. 2,678,028 above-mentioned.

No air will flow through the evaporator-condenser 60 except that which cannot pass through the expansion engine. During 50 pounds oxygen production, complete condensation of the fraction of air passing through the air course 63 of the evaporator-condenser 60 will normally be effected. If more air passes through this course than can be condensed by the available cold provided by evaporation of liquid oxygen flowing at a pressure on the order of 50 p. s. i. g. in the course 62 of the evaporator-condenser 60, the excess on liquefied air will be condensed in the evaporator-condenser coil 78.

The above-mentioned conduit 83 leads to a pressure reducing valve 110 which is adapted to effect a reduction on the order of 60 p. s. i. in the pressure of the fluid (liquid air) which passes through it. The low pressure side of the pressure reducing valve 110 is connected by a conduit 111 with the bottom of the jacket 98 for the strainer 97, and the top of this jacket is connected by a conduit 112 with a jacket 113 for the liquid oxygen 95, there being a conduit 114 leading from the jacket 113 to a connection 115 through which liquid air may be admitted to the top of the column.

The column 73 is illustrated as of the conventional packed type.

Fig. 2 shows in some detail the by-pass mechanism 106. As this is fully disclosed in Patent No. 2,601,764 and in Patent No. 2,588,656, it need not be described at length herein. It includes a disc valve element 118 previously mentioned, which is normally held closed by a spring 119 and is adapted to be moved downwardly and held open by a cylinder and piston mechanism 120 upon supply of operating fluid to a conduit 121. As fully explained in the patents mentioned, the opening movement of the valve is delayed so that a blast of expanded air from "discharge" surge chamber 94 cannot enter the column with such force as to damage the latter.

Figs. 4 and 5 show a suitable form of structure for providing for variable periods of admission to the expansion engine 18. This is the construction of the Paget Patent No. 2,678,028 above mentioned. It need

not be described therefore in detail in this application, and it will suffice to state that when fluid under pressure is supplied to a cylinder and piston mechanism **129** there will be two rollers **130** and **131** in cooperative relation with a cam **132**, and thus a longer period of admission (later cutoff) will be provided. When the cylinder and piston mechanism **129** is vented, cutoff occurs much earlier in the working stroke.

The mode of operation of an oxygen generator of the type selected for illustrative disclosure herein is very fully described in the Collins and Paget Patent No. 2,601,764, to which reference may be had, and therefore it is unnecessary to provide any extended description of temperatures, pressures and operations in this present application, but it will be desirable to have available a relatively brief summary.

It has been noted that the oxygen generator is adapted to produce oxygen at 50 p. s. i. g. or at pressures up to 2000 p. s. i. g. During production of 50-pound oxygen, the expansion engine operates with relatively late cutoff and the by-pass valve **118** is closed. When 2000-pound oxygen is to be the product, the by-pass valve should be open and the engine operated with early cutoff. During starting, for the first couple of hours or so, the by-pass valve should be open and the expansion engine operated with late cutoff. Then during the final period preceding normal production, the expansion engine should be operated with early cutoff. The by-pass valve should be allowed to remain open during this further period. When the system becomes ready to produce oxygen on a suitable basis for an extended period, the control will be by the pressure in a reservoir to which a booster, later described, delivers oxygen and from which oxygen is delivered to a shop line at a pressure considerably above 50 p. s. i. g. Before the system is ready for normal oxygen production it is desirable to use air from the supply line to the generator to effect the necessary controls, but to effect an automatic transfer to booster receiver pressure control after about three hours, the generator to be operated with the by-pass valve open throughout the three hours or so required for normal oxygen to commence, while the expansion engine is operated for the first two hours or so with late cutoff and then switched to early cutoff.

Switching from operation with by-pass valve open and early cutoff to operation with by-pass valve closed and late cutoff and vice versa, is, as noted above adapted to be effected in accordance with the demands imposed by the shop and by means controlled by booster receiver pressure. Desirably, these switchings can be accomplished by a pressure fluid operated valve mechanism effecting the supply of fluid under pressure alternatively to mechanism for shifting the position of the by-pass valve and to mechanism for controlling the point of cutoff in the expansion engine, and the pressure fluid operated valve mechanism can be controlled through appropriate mechanism responsive to the pressure in the receiver to which the booster delivers oxygen. Desirably the fluid actually used for effecting operation of the pressure fluid operated valve mechanism will be drawn from the compressed air supply to the generator because here fluid will be available at appropriate pressure from the first moment of putting the plant into operation, and it is desirable that until oxygen pressure has been built up in the receiver to which the booster discharges, at least to the minimum desired pressure therein, it shall be possible to effect control of the pressure fluid operated valve mechanism by air supplied from another suitable source. It is also important that when the generator ceases to deliver air at a pressure appropriate to compression by the booster which raises the pressure from on the order of 50 p. s. i. g. to on the order of 200 p. s. i. g., the booster intake shall be cut off from communication with the generator delivery line, and that the booster be unloaded, as by inlet valve opening devices. It is further desirable that the connection and disconnection of the booster with the generator delivery line, the loading and unloading of the booster, and the switching of the generator from low pressure oxygen generation to high pressure oxygen generation be coordinately controlled, and that there shall be an overriding control coming into operation when there is reached a predetermined maximum storage chamber pressure of oxygen delivered by the generator when producing at high pressure.

Reference may now be had to Fig. 6 of the drawings which, in conjunction with Fig. 1 and Figs. 2, 3, 4 and 5, will show how the desired operations may be accomplished. It will be noted that a line **140** branches off of the air-under-pressure supply line **11** and that this line is connected with an electromagnetically controlled pilot valve **141**, that it is also connected to a pressure fluid operated valve mechanism **146**, and that it has a branch **147** leading to a control valve **148**. Besides the electromagnetically controlled pilot valve **141**, there is another numbered **143**, and these, the pressure fluid control valve mechanism **146** and the control valve **148** will be described in detail hereinafter.

The oxygen discharge line **25** has branches **151** and **152**. The branch **151** is connected through a check valve **153** with a conduit **154**, which is in turn connected by a conduit **155** with a "storage" **156**, which is adapted to store oxygen at pressures of from 120 p. s. i. g. to 2000 p. s. i. g. This "storage" **156** is desirably of large capacity—sufficient for several hours of operation of the generator when the latter is producing high pressure oxygen. It may be made up in whole or in part of oxygen cylinders, or may be used as a reservoir for high pressure oxygen for the charging of cylinders as well as a source of supply to a booster receiver later described. The conduit **154** is provided with a safety valve **157** set to blow at on the order of 2100 p. s. i. g. or some other suitable value not too far above the desired upper limit of the pressure in the "storage" **156**. A branch **158** leads from the conduit **154** to a pressure responsive switch mechanism **160** later described. A conduit **161**, having a pressure reducing valve **162** between its ends, leads from the "storage" to a receiver **164**, later described. The pressure reducing valve **162** is of the type which is controlled by downstream pressure and is adapted to permit the flow of fluid from the "storage" **156** to the receiver **164** whenever the pressure in the latter gets to a value not much exceeding the desired shop line pressure. For example, pressure reducing valve **162** is adapted to permit flow from the "storage" **156** to the receiver **164** when the pressure in the latter drops to 120 p. s. i. g., in an arrangement in which the shop line pressure, which is taken from the receiver **164**, is to be 115 p. s. i. g.

The branch **152** leads to a pressure fluid operated shutoff valve **166** of any suitable conventional type having pressure fluid operating mechanism diagrammatically shown at **167** and adapted to close the shutoff valve **166** when supplied with operating fluid at an appropriate pressure, and to permit opening of the valve **166** automatically on venting of the operating pressure fluid. Beyond the shutoff valve **166** and controlled by the latter is a conduit **170** provided with a safety valve **171** which may desirably be set to blow at 50 p. s. i. g. The conduit **170** also communicates with a surge chamber **172**, and the surge chamber is connected by a conduit **173** with a booster **175**. This booster is diagrammatically shown, because it may be of any suitable type adapted for the boosting of pressure from on the order of 50 p. s. i. g. to on the order of 200 p. s. i. g. This booster is provided with a conventional unloading mechanism, which is diagrammatically illustrated at **176** and which is pressure fluid operable to effect unloading by pressure supplied to it through a conduit **178** which branches off of a conduit **179** which leads to the pressure fluid operated

mechanism 167 from a conduit 180 which leads off from the pilot valve 143. The unloading mechanism 176 is desirably of the inlet-valve-opening type so familiar in the art of compressors, and which is adapted to permit the free passage of air back and forth through the open inlet valves during unloaded operation. The booster 175 discharges through a conduit 182 to the receiver 164, and fluid is supplied from the receiver 164 through a conduit 183 controlled by a downstream-pressure-controlled pressure-reducing valve 184, which is adapted to permit delivery of fluid from the receiver 164 to the shop line SL whenever the pressure in the latter falls below 115 p. s. i. g. The receiver 164 is provided with a safety valve 185 set to blow at 210 p. s. i. g. The desired pressure range within the receiver 164 is from 125 p. s. i. g. to 200 p. s. i. g., the safety valve 185 preventing any substantial exceeding of the upper value, and the pressure reducing valve 162 precluding normally any drop of the receiver pressure below 125 p. s. i. g. The receiver 164 has another connection with it, a conduit 186. This leads to a pressure responsive switch mechanism 187. Still another connection 188 leads to an automatic control device S which is adapted to shut down the whole generator by stopping the motor, not shown, which drives the air-supplying compressor and with which the expansion engine is connected.

The pressure responsive switch mechanisms 160 and 187 are similar in construction save that the switch proper of the device 160 opens and closes a single circuit while the other switch device, 187, in each of its opposite positions performs a circuit closing function, the circuits which it closes being different ones.

As illustrated in Fig. 6, the conduit 158 leads to a housing 189 in which a bellows 190 is enclosed. The bellows is normally maintained in expanded position by the action of a spring 191 which normally maintains an arm 192 against a lower stop 193. An upper stop 194 is spaced from the lower stop 193 and is engageable by the arm 192 in the upper position of the latter. A spring 196 acts on the end of the arm 192, and is adapted to effect its movement between the stop 193 and the stop 194 with a snap action after the arm 192 is moved upward just past alignment with the axis of the spring 196. A "mercoid switch" 198, in the position shown in Fig. 6, interrupts the circuit which it controls, but in the position it assumes when the arm 192 is against the stop 194 closes the circuit which it controls, which circuit includes conductors 201 and 202, the former leading to the electromagnet 203 of the electromagnetically operated pilot valve 143, from which electromagnet another conductor 204 leads back to one, 205, of a pair of "power" lines 205, 206 the other of which, 206 is connected with the conductor 202.

In the case of the pressure responsive switch 187, the "mercoid" 198' closes a circuit, as previously stated, in each of its opposite positions. The pressure responsive switch mechanism 160 is adapted to effect closing of the circuit which it controls when subjected to a pressure substantially above the setting of the safety valve 157, say 2300 p. s. i. g., and it returns to the position shown in Fig. 6 when the pressure in the "storage" 156 drops to on the order of 1800 p. s. i. g. In the case of the pressure fluid control switch mechanism 187, this is adapted to move its "mercoid" 198' from the position shown to an opposite position when the pressure in the receiver 164 reaches 200 pounds, and to permit its spring 191' to effect a return of the "mercoid" 198' to the position shown after a pressure drop of on the order of 10 or 15 pounds in the receiver 164.

The pressure fluid operated valve mechanism 146 may next be described. As has been noted, this is connected with the conduit 140 and through the latter with the supply line 11 for air under pressure. This valve mechanism is adapted to be normally controlled by a control mechanism 208 governed by the magnetically operated pilot valve 141, and to have an overriding control by the magnetically controlled pilot 143. The mechanism 146 includes a two-spool valve 212 reciprocable in a valve casing 213. The conduit 140 communicates with the valve casing adjacent the longitudinal center of the latter. Conduits 215 and 216 open into the ends of a chamber 217 in the casing 213 in which the valve 212 is reciprocable. Conduit 216 communicates continuously with a vent 218, and conduit 215 is adapted to be connected to a conduit 219 leading to the vent, through a valve 220. Conduit 215 may also be connected, in a different position of the valve 220, with a conduit 221 which communicates with the conduit 140. From the valve chamber 217, there lead two conduits 223 and 224. The first of these communicates with the cylinder and piston mechanism 129 associated with the variable cutoff mechanism. The second is connected with the conduit 121 leading to the by-pass valve control mechanism 120. The valve 220 is arranged in a valve casing 226 with one side of which the conduit 219 communicates, and with a diametrically opposite point in which the conduit 221 communicates. The valve 220 has a right angle port 227 adapted in the position shown in Fig. 6 to connect the conduits 215 and 219 with each other, and in a position 90° counterclockwise from that shown to connect the conduits 215 and 221. When the conduits 215 and 219 are connected together, it will be observed that there is provided a structure in which, depending upon the position of the valve 212, the variable cutoff cylinder and piston mechanism 129 receives pressure while the by-pass valve control is vented, or the by-pass valve control receives pressure, and the cylinder and piston mechanism 129 is vented. With the valve 220 in the position 90° counterclockwise from that shown in Fig. 6, the cutoff varying device 129 receives pressure simultaneously with the supply of pressure to the by-pass valve operating cylinder and piston mechanism 120, when the valve 212 is in a position to effect fluid supply to the latter, a condition desirable only during a part of the starting up period of the generator.

The valve 212 has an operating rod 232. The operating means 208 for this rod includes a cylinder and piston mechanism 236 including a cylinder bore 237 in which there is reciprocable a suitable packed piston 238. The piston 238 has associated with it a spring 239 which presses it towards the cylinder head 240. In the absence of supply of operating fluid to the cylinder bore 237 to act on the upper end of the piston 238, the spring 239 maintains the valve 212 in the position shown in Fig. 6. The cylinder head 240 has a connection 241 for a conduit 242 which connects with the valve mechanism 148. This valve mechanism includes a housing 244 in which there is rotatable a valve element 245 having an angled passage 246. With one side of the valve mechanism, the connection 147, previously mentioned, communicates. With the other side thereof, there is connected the conduit 180 which leads to the magnetically operated pilot valve mechanism 143, the construction of which will shortly be noted.

The valves 220 and 245 are manually adjustable. During normal operation of the oxygen generator, they both occupy the position shown in Fig. 6. The valve element 245 may however occupy a position 90° clockwise from that which is shown, during starting of the generator, for a period of on the order of three hours. The valve 220 may occupy a position 90° counterclockwise from the position shown for a period of about two hours immediately after the generator is started after a period of shutdown. Timing mechanisms for moving the valves automatically from the positions last mentioned to the positions shown may desirably be provided, but such timing mechanisms for moving valves or other elements are so well-known that they are not illustrated in this application. The time operating devices for the

valves 245 and 220, suffice it to say, are so arranged that when the valve 220 is moved to a position 90° counter-clockwise from the position shown in Fig. 6, there will desirably be set in operation an electrical, magnetic, pneumatic or hydraulic device for shifting, at the end of a period on the order of two hours, the valve 220 with a sharp or snap action from that position to the position shown, and in like manner when the valve 245 is shifted to a position 90° clockwise from that shown, there will be placed in operation an electrical, magnetic, pneumatic, or hydraulic device for turning it, at the end of a time period of on the order of three hours, sharply counter-clockwise to the position shown. Shifting of the valves after the desired time lapses could, of course, be left to operator control, but, in order that the system may be rendered completely automatically operative, automatic shift means of the type mentioned may desirably be provided.

It will be noted that when the valves 220 and 245 are in the positions they occupy when the generator is started up, the piston 238 will be forced by compressor discharge pressure into its position opposite that shown in Fig. 6, thus shifting the valve 212 to its opposite position. Then, with the valve 220 in the position 90° counter-clockwise from the one shown, there will be effected fluid supply both to the conduit 223 and the conduit 224, and so the generator will operate with the by-pass valve open and with late cutoff. At the end of two hours or thereabouts, shifting of the valve 220 to the position shown in Fig. 6, while the valve 212 remains in its position opposite that shown in Fig. 6, will permit the expansion engine to operate with early cutoff but the by-pass valve still to remain open. Then at the end of approximately three hours, the shifting of the valve 245 to the position shown in Fig. 6 will place the generator under the control of the magnetic switches 141 and 143, and if these occupy the positions shown in Fig. 6, the expansion engine will operate with late cutoff and the by-pass valve will be closed, the conditions for low pressure production. The structure of the magnetically controlled pilot valves 141 and 143 may now be noted. In the drawings the numbers associated with 143 will be primed, except 203. These pilot valves are conventional devices and each includes a casing 250 on which there is mounted an enclosure 251 in which a plunger 254, adapted for actuation by a solenoid 203, is reciprocable.

The plungers 254 and 254' are in their lower positions in Fig. 6 when the solenoids are not energized, and springs 255 and 255' normally maintain the plungers in such lower position. The plungers are connected with rods 256 and 256' which control the positions of supply and vent valves, shortly to be described.

The casing 250 contains a vented chamber 258, a chamber 259 in which the pressure is to be controlled, and a supply chamber 260. Chambers 258 and 259 are connectible through a valve seat surrounded port 261 controlled by a valve 262 and chamber 259 and chamber 260 are connectible through a valve seat surrounded port 263 controllable by a valve 264. Valves 262 and 264 are so related that but one can be seated at a time. Springs 265 and 265 close the valves whenever closure is possible.

By making the plunger 254 relatively heavy, valve 262 may be maintained open and valve 264 closed in the normal position of the parts, and by making the spring 255 suitably strong there may be provided a bias of the plunger 254 in the direction mentioned, thereby reducing the weight of the plunger necessary.

When the valve 264 is open and the valve 262 is closed, as will be the case when the solenoid 203' is energized, the pressure in the chamber 259 will be that which prevails in the supply chamber 260. When on the other hand, the plunger 254 is in lowered position (that shown in Fig. 6), the pressure in the chamber 259 will be vented through the vent chamber 258.

The rod 256 is connected with the valve 264 so that when the plunger 254 is pulled up the valve 264 will be definitely opened. The valve 262 may have its stem connected to the stem of the valve 264 or merely in end abutting relation with it. In the case of the pilot valve 143, it will be observed that the intermediate chamber 259' has the vented chamber 258' above it, and the chamber 260' from which fluid under pressure is to be supplied to the chamber 259' below the latter, while the valve 264' which controls the supply of fluid to the chamber 259' is the lower valve, and the vent controlling valve 262' is the upper valve. The chambers 259 and 260' are connected with each other by a conduit 270. The chamber 259' is connected with the conduit 180 here above mentioned. In the position of the parts shown in Fig. 6, the space above the piston 238 is vented through the conduit 180, chamber 259', port 263', chamber 260', conduit 270, chamber 259, port 261 and vented chamber 258. If the solenoid 203' is energized, the connection of the chamber 259 with supply will be effected by the opening of the valve 264, valve 262 being forthwith closed. Thus fluid under pressure will be supplied to act on the top of the piston 238. If the solenoid 203 is energized, which will occur only when "storage" pressure reaches on the order of 2300 p. s. i. g., the chamber 259' will be cut off from communication with the conduit 270 and be placed in communication with the chamber 258' which is vented and so remains until the "storage" pressure drops to about 1800 p. s. i. g., which will mean that the generator must operate with late cutoff of the expansion engine and closure of the by-pass valve, and produce oxygen only at low pressure so long as the solenoid 203 is energized under the control of the pressure responsive switch 160.

As has been previously indicated during normal operation of the generator, it will be switched from high to low pressure production and vice versa in accordance with pressure variations in the receiver 164, and attention has been directed to the fact that a pressure responsive switch 187 is provided for the purpose of governing these changes in operation. It has also been noted that this switch is essentially the same as the switch 160, except for the fact that it uses a "mercoid" 198' which closes a circuit in each of its oppositely tilted positions. The diaphragm chamber 189' of the switch 187 has the conduit 186 connect it with the receiver 164. When the receiver pressure reaches 200 pounds, the "mercoid" 198' will be tilted from the position shown in Fig. 6 to an oppositely inclined position and will open the circuit which it establishes in the position of Fig. 6, and close another circuit which will effect energization of the operating solenoid 203' of the pressure switch mechanism 141 and causes the latter to effect fluid supply to the piston 238 when the pilot valve 203 is in the position shown in Fig. 6.

It has been noted earlier that it is desirable not to permit switchings from low to high-pressure operation of the oxygen generator or vice versa without a substantial period of operation according to which ever mode is established, and for that purpose conventional time delay switch mechanisms are employed, these being indicated at 291 and 292 in Figs. 1 and 6, in which latter figure they are shown diagrammatically. When such time delay switch mechanisms are energized as the result of the closing of a primary control switch, they start a motor to operating. Through a cam or the like driven by the motor, there is effected immediate closure of a switch in a holding circuit. The holding circuit includes another switch which is moved to closed position by a solenoid energized concurrently with the starting of the motor. Both switches must be closed for the motor to operate. After the desired (set) period of operation of the motor, the latter is stopped by some variety of adjustable stop means precluding further turning of the cam or the like, which, however has by that time per-

mitted reopening of the first mentioned switch in the holding circuit. Thus the motor, which may be of the torque type cannot be caused to start a complete new cycle merely by continued closure of the primary switch for a period longer than the period for which the relay is set. Through the use of two timer relays, as described, one energized when a control switch is in one position and the other energized when the control switch is in another position, and each having its solenoid operated switch controlling not only its own holding circuit but also the primary switch controlled circuit of the other, it is possible to maintain a solenoid, herein the solenoid **203'**, which forms a part of the solenoid operated switch device **141** energized for a minimum of say half-an-hour when once energized and deenergized for a minimum of half-an-hour whenever it is deenergized.

Now, with the aid of Fig. 6, the arrangements with respect to the timer switch **291** will be described, and like reference numbers, except for primes, will be used with respect to the very similar arrangements with respect to the timer switch **292**. The timer switch **291** includes a motor **294** and the timer element or cam which it controls is indicated at **295**. A lever **296** is shown in position for actuation by the cam. A switch element **297** is movable by the lever to connect stationary contacts **298** and **299**, which are arranged in an interlock circuit which further includes, operated by a solenoid **301**, a switch element **302** which is adapted to be raised by the solenoid to effect connection between stationary contacts **303** and **304**, and, when the solenoid **301** is deenergized, the switch element **302** drops into engagement with other contacts **305** and **306**. The relation of the various contacts, etc. may now be more fully described.

Current is derived from any suitable source of power through conductors **311** and **312**. Conductor **311** is connected by a conductor **313** with one end of the solenoid coil **203'** of the magnetically operated switch **141**. The other end of the solenoid coil is connected by a conductor **314** with a junction point **315**. From this junction point, a conductor **316** extends to one end of the "mercoid" **198'** from which same end another conductor **317** leads to a junction point **318**. From this junction point, a conductor **319** leads to a contact **305'**, and the associated contact **306'** is connected by a conductor **320** to the power line **312**. It will now be apparent that on the attainment of pressure in the receiver **164** to the desired upper limit of operating pressure, say 200 p. s. i. g., and resultant tilting of the "mercoid" **198'**, the solenoid **203'** will be energized and air under pressure will be admitted to act on the piston **238** to force the valve **212** to lowered position, with a resultant flow of air through the conduit **223** to effect early cutoff, and supply of fluid to the cylinder and piston mechanism **120** to effect opening of the by-pass valve **118** and place the generator in condition for high pressure oxygen production. It should here be noted that the contact element **302'** drops at once into engagement with the contacts **305'** and **306'** when the "mercoid" is tilted to its other position from the one shown in Fig. 6. Simultaneously with the establishment of the circuit through the solenoid **203'** by the "mercoid" **198'** there will be established a circuit through the motor **294** of the time delay device **291**, through a conductor **321** connected with the power line **311**, and a conductor **322** connected with the conductor **316** at the junction point **315**. As a result, there will be effected immediate movement by the motor **294** of the contact **297** into engagement with contacts **298** and **299**, and as the solenoid **301** which extends between the conductors **321** and **322** will be simultaneously energized, there will also be movement of the switch element **302** into engagement with the contacts **303** and **304**. Thus there will be established an interlock circuit in parallel with the circuit closed by the "mercoid" **198'**, and this will be maintained closed so long as the contact element **297** is in engagement with the contacts **298** and **299**.

In Fig. 6, time delay switch **291** is shown with its stop arm **325** resting against a stop **327**, a position it occupies when its motor **294** is not energized. In this same figure time delay switch **292** is shown in the position it would occupy after half-an-hour of energization of its motor **294'**. The control element **295'** has completed its movement and permitted lifting of the contact element **297'** out of engagement with the contacts **298'** and **299'** and has its stop arm **325'** in engagement with a stop **326'** which furnishes, as shown, the pivot for the switch operating arm **296'**. The stop arms **325** and **325'** have similar stops **326**, **326'** and **327**, **327'** associated with them. Suitable spring means not shown returns each stop arm to engagement with its stop **327** (or **327'**) on deenergization of the motor which has been energized. The parts are shown as they appear in Fig. 6 because otherwise a shift of the "mercoid" **198'** to its opposite position could be without result, since the time delay switch **292** could not have its operation interrupted, and because so long as the holding coil **301'** was engaged the switch element **302'** would be held in the position shown despite movement of the "mercoid" and so no circuit could be completed through the solenoid **203'**. The motor **294'** is still energized, but can effect no further rotation of the control element **295'**. As soon as the motor **294'** is deenergized, the internal mechanism of the switch **292** will cause the control element **295'** to snap back to its position corresponding to the one shown for the element **295**.

Now, assume that the pressure in the line **186** gets high enough to cause the "mercoid" **198'** to be sharply reversed. This breaks the circuit through the solenoid **301'** and lets the switch element **302'** drop onto the contacts **305'** and **306'**. It breaks the circuit through the motor **294'** and lets the control element **295'** snap back. Closure of the circuit between the contacts **305'** and **306'** permits a circuit to be completed through the solenoid **203'** via conductor **316**, "mercoid" **198'**, conductor **317**, conductor **319**, contact **305'**, switch element **302'**, contact **306'**, and conductor **320** back to the power line **312**. Thereupon the solenoid **301** raises switch element **302** and the motor **294** effects closing of switch **299**, **297**, **298**, and there is produced a holding circuit which cannot be opened by reverse movement of the mercoid, and the solenoid **203'** will be energized until its fixed minimum period of energization established by time delay switch **291** elapses. From what has been described it will be evident that the generator will be required to operate long enough periods, irrespective of whether it is delivering oxygen at high or low pressure, to prevent disorganization of its operation. It might be mentioned that of course with element **302** held in upper position return of the "mercoid" to the position shown could not establish any circuit affecting the solenoid **301** and breaking the holding circuit which shunts the mercoid while the motor **294** is running and the switch **299**, **297**, **298** is closed. It may be mentioned, though it will be evident from what has been said, that the "mercoid" **198'** closes a circuit between the conductors **316'** and **317'** in the position shown and that the shift of the mercury therein to its other end upon its tilting into the other (not shown) position causes connection of the conductors **316** and **317**.

In view of the detailed descriptions of the component structures of the oxygen supply system hereinabove contained, a lengthy description of the mode of operation of the system as a whole is unnecessary. It may be noted, however, that when the system is first started up after a shutdown period, there will be operation of the generator for a period of on the order of two hours with late cutoff of the expansion engine and with the by-pass valve open, and there will then be a period of operation of about another hour with early cutoff of the expansion engine and the by-pass valve still open. During this starting period, the device **208** will be cut off from communi-

cation with the conduit **180** and be connected by the valve **245** with the line **147** which connects with the supply line **11** for compressed air at on the order of 160 p. s. i. g. When the generator is operating normally, its switches from low to high pressure oxygen generation will be under the control of the pressure responsive switch **187** which is governed by the pressure in the receiver **164** to which the booster **175** delivers oxygen produced at low pressure, after boosting its pressure. During this operation, the oxygen leaving the generator passes the open shutoff valve **166** before reaching the intake of the booster **175**. The receiver **164** is connected by the line **186** with the pressure responsive switch mechanism **187**, and is adapted to deliver air through the downstream-pressure-controlled pressure-reducing valve **184** in such a manner as to tend to maintain shop line pressure (the pressure in the shop line SL) at 115 p. s. i. g. The receiver **164** is equipped with a switch mechanism S which would shut down the whole system by stopping the motor which drives the compressor and with which the expansion engine is connected, if receiver pressure rose materially above a pressure which a safety valve **185** is adapted to limit to 210 p. s. i. g. If a demand for air in the shop line SL is great enough so that the full production of oxygen at low pressure delivered by the booster **175** to the receiver **164** is insufficient to maintain the pressure in the latter and such pressure drops to some such value as 120 p. s. i. g., the "storage" **156** will deliver air through the conduit **161** to the receiver **164** past a constant-downstream-pressure pressure-reducing valve **162**, which is adapted to open when the pressure in the receiver **164** falls to 120 pounds or thereabouts.

The booster **175** is provided with unloading mechanism **176** and this unloading mechanism and the pressure fluid operable closing mechanism **167** for the shutoff valve **166** and the arrangement **208** for shifting the oxygen generator from low pressure production to high pressure production are all simultaneously controlled, as the conduit **180** which leads to the mechanism **208** for controlling the generator to determine whether high or low pressure oxygen shall be delivered thereby has a connection **179** branching off from it which leads to the pressure fluid operating mechanism **167** and to the unloading means **176**. As it is not desirable to have the generator operate for too short periods according to either system of oxygen production, there are associated timer switch mechanisms **291** and **292** with the receiver-pressure-responsive switch mechanism **187**, so that the magnetically operated switch **141** which the pressure responsive switch **187** controls cannot be shifted from either of its positions to the other before less than half an hour's operation. The chamber **259** in the magnetically operated switch mechanism **141**, the changes in pressure on which control the mechanisms **167**, **176** and **208** is not connected directly with these mechanisms but is connected with them through another magnetically operated switch mechanism **143** as has been noted, and this last magnetically operated switch mechanism is controlled by a pressure responsive switch **160** which is governed by the pressure in the "storage" **156**, and when the pressure in the "storage" space gets to 2300 pounds the magnetically controlled switch mechanism **143** connects the mechanisms **167**, **176** and **208** all with vent so that the oxygen generator cannot produce oxygen except at low delivery pressure until the "storage" pressure drops to on the order of 1800 pounds.

The discharge line **25** of the oxygen generator is connected through the check valve **153** and conduits **154** and **155** with the "storage" **156**, which is adapted to store oxygen between the desired limits of 120 p. s. i. g. and 2000 p. s. i. g. and from which pressure is adapted to be vented by a safety valve **157** set to blow at 2100 p. s. i. g. As has been previously noted, should the safety valve **157** not, upon opening, preclude continued building up of "storage" pressure, then the automatic control of the oxygen generator limiting it to production at low pressure will be effected, as hereinabove mentioned. A more extended description than this seems unnecessary.

While there is in this application specifically described one form which the invention may assume in practice, it will be understood that this form of the same is shown for purposes of illustration and that the invention may be modified and embodied in various other forms without departing from its spirit or the scope of the appended claims.

It may be noted, however, that the receiver **164** constitutes a conduit subjected to a fluctuating demand, just as definitely as does the shop line SL.

What I claim is:

1. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas, constructed to produce the same at a relatively low pressure or at a relatively high pressure, and having as parts thereof an expansion engine and a column receiving fluid exhausted by the expansion engine, mechanism for changing the point of cutoff of said expansion engine, mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column, means for operating said mechanism for changing the point of cutoff of said expansion engine and said mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column to effect changes of said generator between relatively low pressure production and relatively high pressure production, a discharge line for said generator to which it discharges during either production, a booster to which said discharge line delivers gas, a receiver to which said booster delivers gas, a connection from said receiver to said conduit, and means controlled by pressure variations in said receiver for controlling said operating means.

2. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas, constructed to produce the same at a relatively low pressure or at a relatively high pressure, and having as parts thereof an expansion engine and a column receiving fluid exhausted by the expansion engine, mechanism for changing the point of cutoff of said expansion engine, mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column, means for operating said mechanism for changing the point of cutoff of said expansion engine and said mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column to effect changes of said generator between relatively low pressure production and relatively high pressure production, a discharge line for said generator to which it discharges during either production, a booster to which said discharge line delivers gas, a receiver to which said booster delivers gas, a connection from said receiver to said conduit, means controlled by pressure variations in said receiver for controlling said operating means, and means for preventing changes from relatively low to relatively high pressure production and vice versa until whatever system of production is in use has been in use for a predetermined period.

3. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas, constructed to produce the same at a relatively low pressure or at a relatively high pressure, and having as parts thereof an expansion engine and a column receiving fluid exhausted by the expansion engine, mechanism for changing the point of cutoff of said expansion engine, mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column, means for operating said mechanism for changing the point of cutoff of said expansion engine and said mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column to effect changes of said generator between relatively low pressure production and relatively high pressure production, a discharge line for said generator to which it

discharges during either production, a booster to which said discharge line delivers gas, a stop valve between said booster and said discharge line, a receiver to which said booster delivers gas, a connection from said receiver to said conduit, and means controlled by pressure variations in said receiver for controlling said operating means and said stop valve.

4. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas, constructed to produce the same at a relatively low pressure or at a relatively high pressure, and having as parts thereof an expansion engine and a column receiving fluid exhausted by the expansion engine, mechanism for changing the point of cutoff of said expansion engine, mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column, means for operating said mechanism for changing the point of cutoff of said expansion engine and said mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column to effect changes of said generator between relatively low pressure production and relatively high pressure production, a discharge line for said generator to which it discharges during either production, a booster to which said discharge line delivers gas, said booster having unloading means, a receiver to which said booster delivers gas, a connection from said receiver to said conduit, and means controlled by pressure variations in said receiver for controlling said operating means and said unloading means.

5. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas, constructed to produce the same at a relatively low pressure or at a relatively high pressure, and having as parts thereof an expansion engine and a column receiving fluid exhausted by the expansion engine, mechanism for changing the point of cutoff of said expansion engine, mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column, means for operating said mechanism for changing the point of cutoff of said expansion engine and said mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column to effect changes of said generator between relatively low pressure production and relatively high pressure production, a discharge line for said generator to which it discharges during either production, a booster to which said discharge line delivers gas, a stop valve between said booster and said discharge line, a receiver to which said booster delivers gas, a connection from said receiver to said conduit, means controlled by pressure variations in said receiver for controlling said operating means and said stop valve, and means for preventing changes from relatively low to relatively high pressure production and vice versa until whatever system of production is in use has been in use for a predetermined period.

6. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas, constructed to produce the same at a relatively low pressure or at a relatively high pressure, and having as parts thereof an expansion engine and a column receiving fluid exhausted by the expansion engine, mechanism for changing the point of cutoff of said expansion engine, mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column, means for operating said mechanism for changing the point of cutoff of said expansion engine and said mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column to effect changes of said generator between relatively low pressure production and relatively high pressure production, a discharge line for said generator to which it discharges during einther production, a booster to which said discharge line delivers gas, said booster having unloading means, a receiver to which said booster delivers gas, a connection from said receiver to said conduit, and means controlled by pressure variations in said receiver for controlling said operating means and said unloading means, and means for preventing changes from relatively low to relatively high pressure production and vice versa until whatever system of production is in use has been in use for for a predetermined period.

7. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas, constructed to produce the same at a relatively low pressure or at a relatively high pressure, and having as parts thereof an expansion engine and a column receiving fluid exhausted by the expansion engine, mechanism for changing the point of cutoff of said expansion engine, mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column, means for operating said mechanism for changing the point of cutoff of said expansion engine and said mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column to effect changes of said generator between relatively low pressure production and relatively high pressure production, a discharge line for said generator to which it discharges during either production, a booster to which said discharge line delivers gas, a stop valve between said booster and said discharge line, said booster having unloading means, a receiver to which said booster delivers gas, a connection from said receiver to said conduit, means controlled by pressure variations in said receiver for controlling said operating means and said stop valve and said unloading means, and means for preventing changes from relatively low to relatively high pressure production and vice versa until whatever system of production is in use has been in use for a predetermined period.

8. In an apparatus for supplying a gas to a conduit subjected to a fluctuating demand, a generator for the gas having as parts thereof an expansion engine and a column receiving fluid exhausted by the expansion engine, mechanism for changing the point of cutoff of said expansion engine, mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column, and means for governing the operation of said mechanisms including (*a*) a device responsive to the pressure in said conduit and shiftable to different control-changing positions when the pressure in said conduit arrives at different predetermined values and (*b*) associated means for precluding said mechanisms from rechanging the point of cutoff of said expansion engine and the point of introduction of fluid exhausted by the expansion engine into the column, after once changing the same, for a substantial period notwithstanding that the pressure in said conduit may in a shorter period change from the predetermined value at which said change was effected to the predetermined value appropriate to rechange.

9. In an apparatus for supplying a gas to a conduit subjected to a fluctuating demand, a generator for the gas having as parts thereof an expansion engine and a column receiving fluid exhausted by the expansion engine, mechanism for changing the point of cutoff of said expansion engine, mechanism for changing the point of introduction of fluid exhausted by the expansion engine into the column, and means including a device responsive to the pressure in said conduit and associated timer switch means for limiting the frequency of operation of said mechanisms, for governing the operation of said mechanisms.

10. In an apparatus for supplying a gas to a conduit which is subjected to a fluctuating demand, a generator for the gas having as parts thereof an expansion engine and a column receiving fluid exhausted by said expansion engine, pressure fluid controlled mechanism for changing the point of cutoff of said expansion engine, pressure

fluid controlled mechanism for changing the point of introduction into the column of fluid exhausted by the expansion engine, valve mechanism for effecting the subjection of said pressure fluid controlled mechanisms to an operating fluid and relieving them of such subjection and means for governing said valve mechanism including (*a*) a device responsive to the pressure in said conduit and shiftable to different valve mechanism-controlling positions when the pressure in said conduit arrives at different predetermined values and (*b*) associated means for precluding said valve mechanism from effecting rechanging of the point of cutoff of said expansion engine and the point of introduction of fluid exhausted by the expansion engine into the column, after effecting a change of the same, for a substantial period notwithstanding that the pressure in said conduit may in a shorter period change from the predetermined value at which said change was effected to the predetermined value appropriate to rechange.

11. In an apparatus for supplying a gas to a conduit which is subjected to a fluctuating demand, a generator for the gas having as parts thereof an expansion engine and a column receiving fluid exhausted by said expansion engine, mechanism for changing the point of cutoff of said expansion engine, mechanism for changing the point of introduction into the column of fluid exhausted by the expansion engine, a control device responsive to the pressure in said conduit, and mechanism governed by said control device and associated timer switch means for limiting the frequency of operation of said mechanisms, for effecting the subjection of said mechanisms for changing the point of cutoff of the expansion engine and for changing the point of introduction into the column of fluid exhausted by the expansion engine, to an operating medium and relieving them from such subjection.

12. In a controlling apparatus for a gas generator which constitutes a source of gas supply for a delivery conduit and includes an expansion engine having at least two different points of cutoff, a column receiving the exhaust of said expansion engine, and a valve movable to change the point of delivery of the exhaust of said expansion engine to the column, a device for effecting change in the point of cutoff, a device for effecting a change in the position of said valve, means movable to control action upon each of said devices of an operating medium, means including a device responsive to the pressure in said conduit for which said generator constitutes a source of supply for governing the position of said means movable to control the action of said operating medium upon said devices, said device having two control changing positions between which it shifts upon predetermined pressure changes in said conduit, and means for necessitating the elapsing of a predetermined minimum time between a pair of successive changes in position of said means movable to control the action of said operating medium upon said devices, notwithstanding a change of the pressure in said conduit, in a shorter period, which causes said device to change from one to another of said two positions.

13. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas including an expansion engine, a column for receiving fluid exhausted by said expansion engine and means for delivering such fluid to the column at different points, said generator adapted to produce said gas at widely differing pressures when said expansion engine is operated with late cutoff and its exhaust enters the column at a higher point and when said expansion engine is operated with earlier cutoff and its exhaust enters the column at a lower point, means operable to alter the cutoff of the expansion engine and the point of delivery of its exhaust to the column to switch production from lower to higher gas production and vice versa, a discharge line to which said generator delivers product gas during both productions, a high pressure storage having a check-valved connection with said discharge line, a booster having a stop valve controlled connection with said discharge line, and a receiver connected to said conduit and to which said booster discharges.

14. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas including an expansion engine, a column for receiving fluid exhausted by said expansion engine and means for delivering such fluid to the column at different points, said generator adapted to produce said gas at widely differing pressures when said expansion engine is operated with late cutoff and its exhaust enters the column at a higher point and when said expansion engine is operated with earlier cutoff and its exhaust enters the column at a lower point, means operable to alter the cutoff of the expansion engine and the point of delivery of its exhaust to the column to switch production from lower to higher gas production and vice versa, a discharge line to which said generator delivers product gas during both productions, a high pressure storage having a check-valved connection with said discharge line, a booster having unloading means and a stop valve controlled connection with said discharge line, and a receiver connected to said conduit and to which said booster discharges.

15. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas including an expansion engine, a column for receiving fluid exhausted by said expansion engine and means for delivering such fluid to the column at different points, said generator adapted to produce said gas at widely differing pressures when said expansion engine is operated with late cutoff and its exhaust enters the column at a higher point and when said expansion engine is operated with earlier cutoff and its exhaust enters the column at a lower point, means operable to alter the cutoff of the expansion engine and the point of delivery of its exhaust to the column to switch production from lower to higher gas production and vice versa, a discharge line to which said generator delivers product gas during both productions, a high pressure storage having a check-valved connection with said discharge line, a booster having a stop valve controlled connection with said discharge line, a receiver connected to said conduit and to which said booster discharges, and means responsive to receiver pressure for controlling said second mentioned means and said stop valve.

16. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas including an expansion engine, a column for receiving fluid exhausted by said expansion engine and means for delivering such fluid to the column at different points, said generator adapted to produce said gas at widely differing pressures when said expansion engine is operated with late cutoff and its exhaust enters the column at a higher point and when said expansion engine is operated with earlier cutoff and its exhaust enters the column at a lower point, means operable to alter the cutoff of the expansion engine and the point of delivery of its exhaust to the column to switch production from lower to higher gas production and vice versa, a discharge line to which said generator delivers product gas during both productions, a high pressure storage having a check-valved connection with said discharge line, a booster having unloading means and a stop valve controlled connection with said discharge line, a receiver connected to said conduit and to which said booster discharges, and means responsive to receiver pressure for controlling said second mentioned means, said unloading means and said stop valve.

17. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas including an expansion engine, a column for receiving fluid exhausted by said expansion engine and means for delivering such fluid to the column at dif-

ferent points, said generator adapted to produce said gas at widely differing pressures when said expansion engine is operated with late cutoff and its exhaust enters the column at a higher point and when said expansion engine is operated with earlier cutoff and its exhaust enters the column at a lower point, means operable to alter the cutoff of the expansion engine and the point of delivery of its exhaust to the column to switch production from lower to higher gas production and vice versa, a discharge line to which said generator delivers product gas during both productions, a high pressure storage having a check-valved connection with said discharge line, a booster having a stop valve controlled connection with said discharge line, a receiver connected to said conduit and to which said booster discharges, and a conduit having a downstream-pressure governed reducing valve therein and connecting said high pressure storage with said receiver.

18. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas including an expansion engine, a column for receiving fluid exhausted by said expansion engine and means for delivering such fluid to the column at different points, said generator adapted to produce said gas at widely differing pressures when said expansion engine is operated with late cutoff and its exhaust enters the column at a higher point and when said expansion engine is operated with earlier cutoff and its exhaust enters the column at a lower point, means operable to alter the cutoff of the expansion engine and the point of delivery of its exhaust to the column to switch production from lower to higher gas production and vice versa, a discharge line to which said generator delivers product gas during both productions, a high pressure storage having a check-valved connection with said discharge line, a booster having a stop valve controlled connection with said discharge line, a receiver connected to said conduit and to which said booster discharges, means responsive to receiver pressure for controlling said second mentioned means and said stop valve, and means responsive to high pressure storage pressure for overriding said last mentioned control.

19. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas including an expansion engine, a column for receiving fluid exhausted by said expansion engine and means for delivering such fluid to the column at different points, said generator adapted to produce said gas at widely differing pressures when said expansion engine is operated with late cutoff and its exhaust enters

the column at a higher point and when said expansion engine is operated with earlier cutoff and its exhaust enters the column at a lower point, means operable to alter the cutoff of the expansion engine and the point of delivery of its exhaust to the column to switch production from lower to higher gas production and vice versa, a discharge line to which said generator delivers product gas during both productions, a high pressure storage having a check-valved connection with said discharge line, a booster having unloading means and a stop valve controlled connection with said discharge line, a receiver connected to said conduit and to which said booster discharges, means responsive to receiver pressure for controlling said second mentioned means, said unloading means and said stop valve, and means responsive to high pressure storage pressure for overriding said last mentioned control.

20. In an apparatus for supplying a gas under pressure to a conduit subjected to a fluctuating demand, a generator for the gas including an expansion engine, a column for receiving fluid exhausted by said expansion engine and means for delivering such fluid to the column at different points, said generator adapted to produce said gas at widely differing pressures when said expansion engine is operated with late cutoff and its exhaust enters the column at a higher point and when said expansion engine is operated with earlier cutoff and its exhaust enters the column at a lower point, means operable to alter the cutoff of the expansion engine and the point of delivery of its exhaust to the column to switch production from lower to higher gas production and vice versa, a discharge line to which said generator delivers product gas during both productions, a high pressure storage having a check-valved connection with said discharge line, a booster having unloading means and a stop valve controlled connection with said discharge line, a receiver connected to said conduit and to which said booster discharges, means responsive to receiver pressure and having associated means for limiting its reversals of control for controlling said second mentioned means, said unloading means and said stop valve, and means responsive to high pressure storage pressure for overriding said last mentioned control.

References Cited in the file of this patent

UNITED STATES PATENTS

2,501,999	Fausek	Mar. 28, 1950
2,588,656	Paget	Mar. 11, 1952
2,601,764	Collins et al.	July 1, 1952