

July 6, 1965

W. E. BERKEY ETAL

3,192,686

DEHYDRATOR METHOD

Filed April 10, 1961

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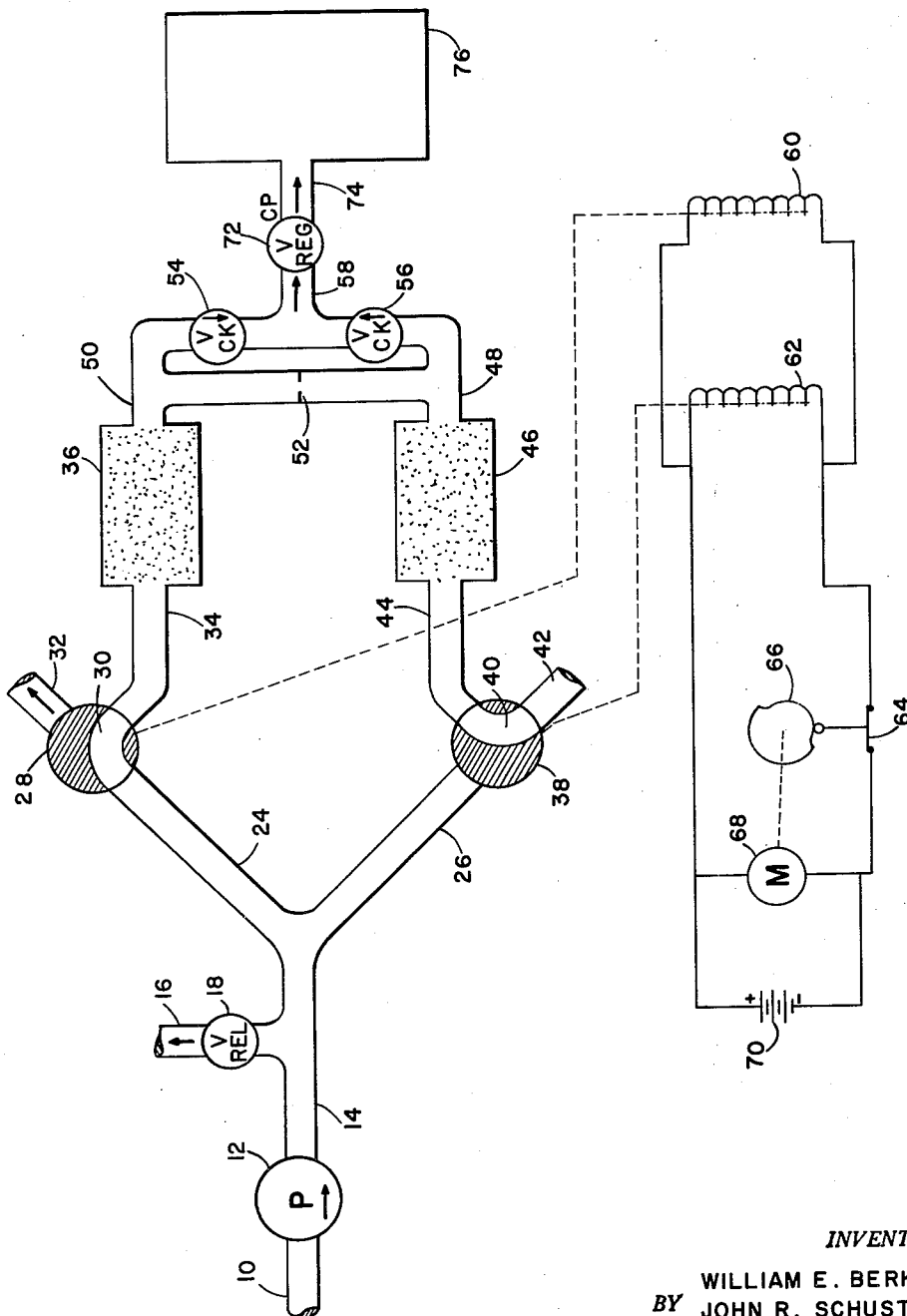


FIG. 1

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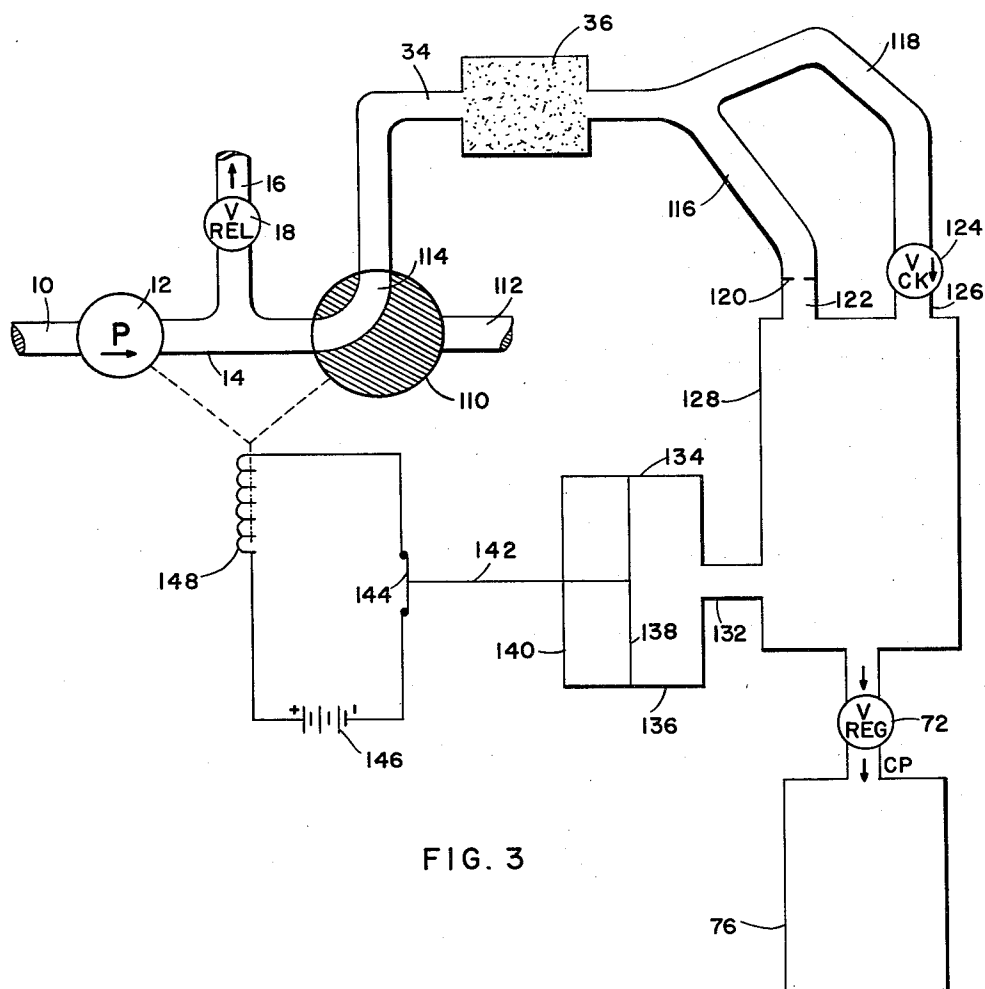
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5 Sheets-Sheet 3



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DEHYDRATOR METHOD

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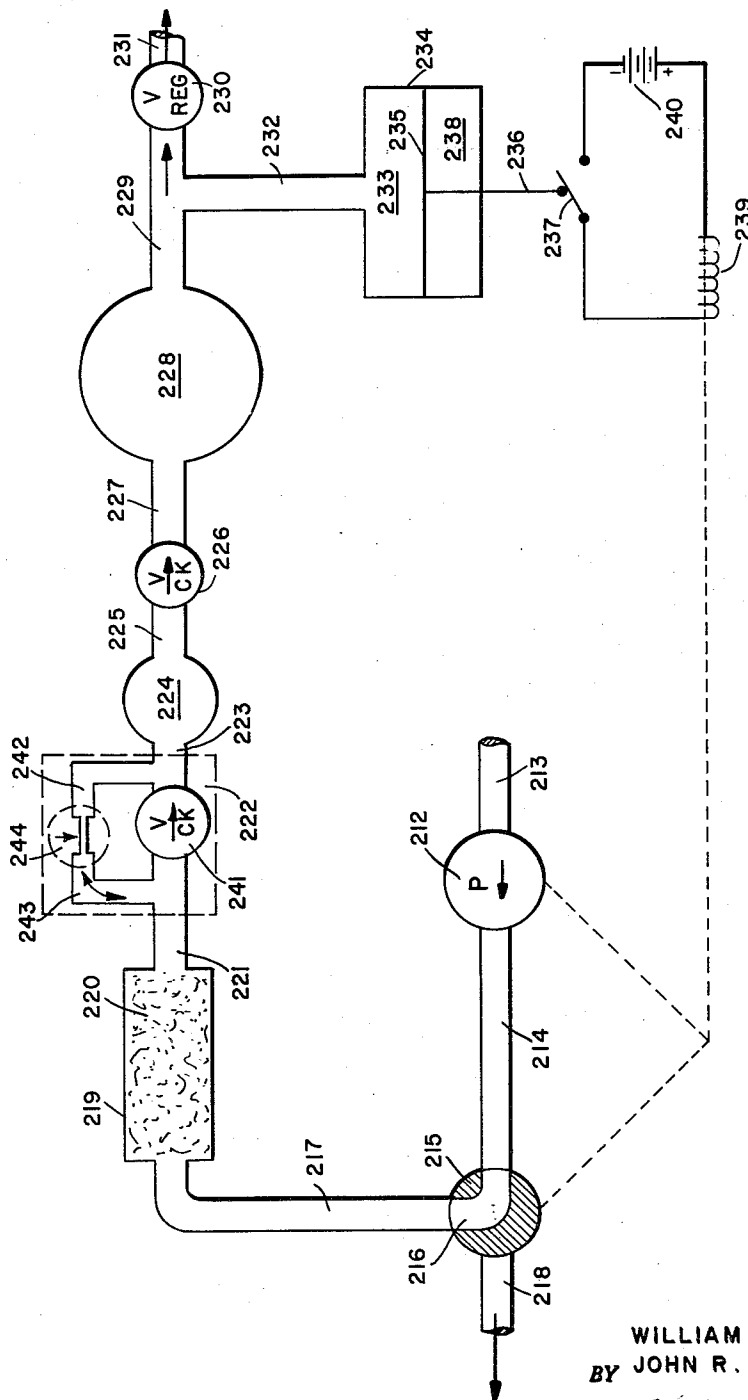


FIG. 4

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3,192,686

DEHYDRATOR METHOD

William E. Berkey and John R. Schuster, Elyria, Ohio, assignors, by mesne assignments, to Lear Siegler, Inc., Santa Monica, Calif., a corporation of Delaware
Filed Apr. 10, 1961, Ser. No. 103,953
1 Claim. (Cl. 55—21)

This invention pertains to a dehydrator method, and more particularly to an automatically reactivated dehydrator method, and is a continuation-in-part of the co-pending application by the same inventor bearing Serial No. 20,773, filed April 6, 1960, now abandoned, and assigned to the assignee of this application.

Heretofore it has been necessary to reactivate dehydrators by applying heat from an external source to the desiccant material to drive out the moisture and to reactivate this material so that it is again ready to be used in the system.

The necessity for a heating method required that the dehydrator be large and cumbersome and required that an external source of heat energy be utilized.

The dehydrator method of this invention automatically reactivates the desiccant material. The air or gas is dried under a comparatively high pressure which generates heat in the dehydrator. Then a portion of the dried air, under a reduced pressure, is driven in a reversed direction through the dehydrators to utilize the remaining heat in the dehydrators plus the increased ability of low pressure gas (compared to high pressure gas) to absorb moisture from the desiccant material. The low pressure gas is then exhausted into the air or a suitable receptacle.

In one embodiment, the dehydrator method contemplated by this invention utilizes a pair of individual dehydrators, one of which dries pressurized gas which is applied thereto, while the second dehydrator is reactivated by bleeding, at a reduced pressure, a portion of the dry gas therethrough in a reversed direction. A timed valve is utilized to selectively connect the first and second dehydrators in sequence between a source of moisture containing high pressure gas and a receiving conduit of moisture free gas. A portion of the dry gas is automatically reduced in pressure and channeled in a reverse direction through the reactivating dehydrator to remove moisture from the desiccant material and to transfer the moisture either into the atmosphere or into a wet air sump.

Another embodiment of this invention utilizes a single dehydrator which is connected between a source of moisture containing high pressure gas and a ballast tank of dry gas. When the ballast tank is charged to a predetermined pressure, the dehydrator is disconnected, in response to a pressure sensitive device in the ballast tank, from the source of high pressure gas. A portion of the dry gas in the ballast tank is channeled, at a reduced pressure, in a reversed direction through the dehydrator to remove moisture to reactivate the dehydrator. The moist gas is exhausted through the dehydrator to the atmosphere or to a wet gas sump.

Therefore, it is an object of this invention to provide a dehydrator method which is reactivated without the application of external heat.

Another object of this invention is to provide a dehydrator method wherein a portion of the dry air output is utilized to reactivate the dehydrators.

Another object of this invention is to provide a method for supplying a fractional gaseous component of a gaseous mixture from a storage vessel to a region of requirement with only an intermittent replenishment of the fractional gaseous component.

It is another object of this invention to provide a method for supplying a processed gaseous component to a place

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of use, which will require only an intermittent feeding of an unprocessed gaseous mixture.

Other objects will become apparent from the following description when taken in connection with the accompanying drawings in which:

FIG. 1 is a flow diagram of a first embodiment of this invention;

FIG. 2 is a flow diagram of a second embodiment of this invention;

FIG. 3 is a flow diagram of a third embodiment of this invention;

FIG. 4 is a flow diagram of a fourth embodiment of this invention, and

FIG. 5 is a flow diagram of a fifth embodiment of this invention.

In FIG. 1, an air or gas compressor 12 is connected through conduit 10 to the atmosphere. A pressure relief valve 18 which exhausts to the atmosphere is connected to the output of compressor 12. A pair of three-way, two-port valves 28 and 39 are positioned to connect conduits 34 and 44 either to conduits 24 and 26 or to conduits 32 and 42. Conduit 34 is connected to one end of dehydrator 36.

Within dehydrator 36 is a desiccant material such as (for example only) silica gel, calcium chloride, or alkali metal aluminosilicates. The desiccant material is preferably divided into small granules and placed in the path of the gas to cause the gas to pass through and over the desiccant.

Dry gas is discharged, under high pressure, from dehydrator 36 into conduit 50. Conduit 50 is connected through one-way check valve 54 to conduit 53 which, in turn, is connected through a constant output pressure valve 72 to a tank 76 or other useful inclosure such as, for example, a radar inclosure. Conduit 50 is connected through orifice 52 to conduit 48.

A shuttle valve may be utilized in place of check valves 54 and 56 and may further be combined with orifice 52 as an integral part of the assembly.

Three-way, two-port valves 28 and 38 are connected in opposition. Solenoids 60 and 62 are mechanically connected to control the motion of valves 28 and 38. Solenoids 60 and 62 are electrically connected to operate together. When solenoids 60 and 62 are in one position, channel 30 of valve 28 connects conduits 24 and 34 while channel 40 of valve 38 connects conduits 42 and 44. When solenoids 60 and 62 are positioned in their second position, channel 30 of valve 28 connects conduits 32 and 34 while channel 40 of valve 38 connects conduits 26 and 44.

Solenoids 60 and 62 are connected to a voltage source 70 through a switch 64. Switch 64 is operated by a timing mechanism such as (for example) motor 68 which drives cam 66. Of course, other timing means (not shown) may be utilized in place of motor 68 and cam 66. In one preferred embodiment of this device, the timing mechanism of motor 68 and cam 66 causes solenoids 62 and 60 to be in one position for approximately one minute then to shift to their second position. After another minute, the cycling of solenoids 62 and 60 is repeated.

In FIGURE 2, a four-way, four-port valve 78 with channels 80 and 82 has been substituted for the two three-way, two-port valves 28 and 38 of FIGURE 1. Solenoid 104 has been substituted for the pair of solenoids 62 and 60 of FIG. 1. Solenoid 104 controls valve 78 for two positions in response to the position of switch 64. When valve 78 is in one position, channel 80 connects conduits 22 and 34 while channel 82 connects conduits 44 and 84. Conduit 84 exhausts to the atmosphere. When valve 78 is moved by solenoid 104 to its second position, chan-

nel 80 connects conduits 34 and 84 while channel 82 connects conduits 22 and 44.

The plumbing connected to conduits 48 and 50 of FIG. 2 is different from that of FIG. 1. In FIG. 2, conduit 50 is connected through conduit 36 and one-way check valve 54 to conduit 74. Conduit 48 is connected through conduit 38 and one-way check valve 56 to conduit 74. Conduit 74 is connected through conduit 90 to constant input pressure regulator 98. Regulator 98 is connected by its output through one-way check valve 94 to conduit 50 and through check valve 102 to conduit 48. Conduit 74 is connected to tank 76 which may be (for example) a closed container which surrounds a piece of electronic equipment.

In FIG. 3, compressor 12 is connected through conduit 10 to a source of gas. The high pressure side of compressor 12 is connected to conduit 14. Pressure relief valve 18, connected to control the pressure in conduit 14, is vented through conduit 16 to the atmosphere. Conduit 14 is connected to three-way, two-port valve 110. Channel 114 of valve 110 is adapted in its first position to connect conduits 14 and 34 and in its second position to connect conduits 34 and 112. Conduit 112 is vented to the atmosphere. Valve 110 is controlled by solenoid 143 in response to the position of switch 144. Conduit 34 is connected through dehydrator 36 to conduits 116 and 118. Conduit 116 is connected through orifice 120 and conduit 122 to ballast tank 128. Conduit 118 is connected through one-way check valve 124 and conduit 126 to ballast tank 128.

A pressure responsive device 134, such as (for example) a diaphragm device has a diaphragm 138 adapted to move in response to pressure differential across its surface. Chamber 136 of device 134 is connected through conduit 132 to ballast tank 128 while chamber 140 may, alternatively, be connected to the atmosphere or evacuated. A push rod 142 is attached to the center of diaphragm 138 to be controlled in response to the position of diaphragm 138. Push rod 142 is attached to control the position of switch 144. The opening and closing of switch 144 is thereby controlled in response to motion of diaphragm 138. Solenoid 143 is connected to voltage source 146 through switch 144 simultaneously to control the motion of valve 110 and to energize and de-energize compressor 12. When valve 110 is positioned as shown in FIG. 3, compressor 12 is energized. When conduit 114 of valve 110 connects 34 and 112, compressor 12 is de-energized.

Ballast tank 128 is connected through constant pressure output regulator 72 to a tank 76 or other useful enclosure such as (for example) a container which encloses a piece of equipment.

In operation, compressor 12 pumps gas or air from conduit 10 into conduit 14 at a higher pressure. If the pressure in conduit 14 exceeds a predetermined value, relief valve 18 exhausts conduit 14 through conduit 16 to the atmosphere. With valves 28 and 38 in the position shown, high pressure gas is applied through conduits 14, 22 and 24, through channel 30, and through conduit 34 to a first end dehydrator 36. Compressed gas is able to carry less water than uncompressed gas. Compressor 12 causes water vapor to condense in conduit 34. Water vapor which does not condense in conduit 34 is adsorbed by the desiccant material within dehydrator 36. The gas which is delivered from the second end of dehydrator 36 to conduit 50 is extremely dry. High pressure gas in conduit 50 operates check valve 54 to cause the gas to flow into conduit 58, thence through pressure regulator 72 into conduit 74 and tank 76.

Dry air also flows through orifice 52, where the pressure is reduced into conduit 48. The pressure is reduced through orifice 52 to a value below that necessary to operate check valve 56. Low pressure dry air flows into dehydrator 46 at its second end and out of dehydrator 46 at its first end into conduit 44, thence through channel

40 of valve 38 and conduit 42 to be exhausted into the atmosphere. If the gas were toxic and the like, suitable exhaust sumps could be available to exhaust conduit 42 and conduit 32.

Voltage source 70 drives timing motor 68 which mechanically drives cam 66 to operate switch 64. Switch 64 is timed by the motion of cam 66 to operate in approximately half the time in an open and half the time in a closed position. When switch 64 is closed, solenoids 62 and 60 are energized to cause valves 28 and 38 to be positioned in a predetermined position (for example the position shown in FIG. 1). During the next half cycle of cam 66, solenoids 62 and 60 are de-energized to cause valves 28 and 38 to take their second position (for example, in FIG. 1, a position whereby channel 30 connects conduits 32 and 34, while channel 40 connects conduits 26 and 44).

When valves 28 and 38 have been moved so that channel 30 connects conduits 32 and 34 and channel 40 connects conduits 26 and 44, high pressure gas is delivered to the first or wet end of dehydrator 46 through conduits 26 and 44 and through channel 40. Moisture is removed from the gas as the gas passes through the desiccant material of dehydrator 46 to the second or dry end of dehydrator 46 into conduit 48. High pressure gas opens check valve 56 to cause dry gas to flow into conduit 58, thence through constant output pressure valve 72 into tank 76. Gas flows from conduit 48 through orifice 52 into conduit 50. Orifice 52 reduces the pressure of the gas so that the dry gas in conduit 50 is not of sufficiently high pressure to open check valve 54. The low pressure dry gas in conduit 50 is reverse-fed through dehydrator 36 from its second to its first end to reactivate dehydrator 36 by removing stored moisture. The moisture is carried in the low pressure air through conduit 34, channel 30, and conduit 32 to the outside atmosphere.

It is to be noted that when the dehydrators are re-activated, they have just completed a cycle during which moisture was being absorbed from the gas which passes therethrough. When moisture is absorbed by the desiccant material, heat is generated. By immediately reverse-cycling low pressure dry gas through a dehydrator while it is still warm, an increased efficiency of utilization of heat is achieved to dry the desiccant material and to cause the dry gas to remove the moisture from the desiccant material.

It is further to be noted that one end (here designated the second end) of each dehydrator must be kept dry. Hence during the reactivating cycle, the dehydrators are reverse-fed to avoid wet gas at the dry end of the dehydrators.

In FIG. 2, voltage is applied to motor 68 from voltage source 70 to cause motor 68 to turn cam 66. Motor 68 together with cam 66 is a timing device which is adapted to open and close switch 64 in a predetermined timing sequence. In the preferable time sequence, switch 64 is closed half of the time and open half of the time. When switch 64 is closed, solenoid 104 is energized to cause valve 78 to be in one of two distinct positions. When solenoid 104 is de-energized, valve 78 is moved by spring or other means (not shown) into a second position. For example, with solenoid 104 energized, valve 78 may be positioned as shown in the figures to cause channel 80 to connect conduits 22 and 34 and to cause channel 82 to connect conduits 44 and 84. It is to be noted that the four-way, four-port valve 78 could alternatively replace the two three-way, two-port valves in the device of FIG. 1.

Compressor 12 compresses gas or air from conduit 10. Relief valve 18 exhausts conduit 14 to the atmosphere when the pressure in conduit 14 reaches an excessive predetermined value.

With valves positioned as shown in FIG. 2, high pressure air or gas is channeled from conduit 14 into conduit 34, thence through dehydrator 36 into conduit 50.

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High pressure dry gas in conduit 50 actuates check valve 54 to cause dry air to flow through conduit 74 into tank 76. At the same time, conduit 48 is vented through dehydrator 46 and conduits 44 and 84 and through channel 82 to the atmosphere. Constant input pressure regulator 98 maintains the pressure in conduits 74 and 90 at some predetermined high pressure. When the pressure in conduit 90 tends to increase, pressure regulator 98 bleeds off some of the gas in conduit 90 either into conduit 96 or into conduit 100. With the flow of gas from a high pressure region in conduit 50 through check valve 54, the output flow from pressure regulator 98 will actuate check valve 102 to cause a reverse flow of gas through conduit 48, through dehydrator 46 from the second or dry end of the first or wet end, and will carry moisture from dehydrator 46 through conduits 44 and 84 into the atmosphere, or into some appropriate sump.

When solenoid 104 is cycled to its alternate state which causes valve 78 to rotate a quarter turn to connect conduits 34 and 84 and to connect conduits 22 and 44, high pressure wet gas flows from conduit 22 into conduit 44, through dehydrator 46 from the first or wet end to the second or dry end, through conduits 48 and 88, through check valve 56 and conduit 74 into tank 76. Conduit 50 is vented to the atmosphere through dehydrator 36, conduit 34 and conduit 84. Excessive gas in conduit 90 is bled off through constant pressure input regulator 98, conduit 96, check valve 94, conduit 92, conduit 50, dehydrator 36 from the second or dry end to the first or wet end, conduit 34, channel 80 and conduit 84 to the atmosphere.

In the device of FIG. 3, compressor 12 operates when valve 110 is in the position shown in the figure. Compressor 12 compresses air or other gas to conduit 14. Pressure relief valve 18 releases gas to the atmosphere when the pressure in conduit 14 exceeds a predetermined value. High pressure moist gas is supplied to dehydrator 36 through conduits 14 and 34 and through channel 114 of valve 110. Moist gas is channeled through dehydrator 36 where the moisture is removed to supply high pressure dry gas to conduits 116 and 118. High pressure gas in conduit 118 operates check valve 124 to charge ballast tank 128. Gas also flows through orifice 120 into tank 128.

Pressure sensitive device 134 is connected to be responsive to the pressure in ballast tank 128. As the pressure in ballast tank 128 increases, the pressure in chamber 136 also increases which moves diaphragm 138 to the left to close switch 144. When switch 144 is closed, voltage source 146 is connected to energize solenoid 148 which stops compressor 12 and causes valve 110 to move to its second position wherein channel 114 connects conduits 34 and 112. Conduit 112 is exhausted into the atmosphere or to a sump.

With channel 114 connecting conduits 34 and 112, conduit 116 is vented to the atmosphere through dehydrator 36, conduits 34 and 112, and channel 114. The pressure differential across orifice 120 causes dry gas to flow from conduit 122 into conduit 116, thence from the second or dry end to the first or wet end of dehydrator 36, through conduits 34, 112 and through channel 114 to the atmosphere to reactivate dehydrator 36.

As the pressure in tank 128 decreases, diaphragm 138 moves to the right to open switch 144. When switch 144 is opened, compressor 12 is started and valve 110 moves to the position shown wherein conduit 114 connects to conduits 14 and 34.

Dry gas at constant output pressure is supplied to tank 76 through pressure regulator 72.

It will be obvious to those skilled in the art that switch 144 could be arranged in the circuit of solenoid 148, and solenoid 148 could be connected to valve 110 and compressor 12 so that closure of switch 144 would start rather than stop compressor 12 and would connect valve 110 as shown, rather than in its alternate position.

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Thus, the device of this invention is adapted to provide exceedingly dry gas with a recharging dehydrator cycle which is adapted to automatically provide a continuing supply of dry gas in accordance with predetermined requirements. Further, the dry gas which is obtained under high pressure is reduced in pressure to recharge the dehydrators without the addition of external heat.

Another embodiment of this invention is shown in FIG. 4, not drawn to scale, in which compressor 212 is connected through conduit 213 to a source of gas, which can be moisture-containing air. The high pressure side of the compressor 212 is connected to conduit 214 which in turn is connected to a three-way, two-port valve means 215. Channel 216 of valve 215 is adapted in its first position to connect conduits 214 and 217 and in its second position to connect conduit 217 to conduit 218 which is vented to the atmosphere or to an exhaust reservoir. When the compressor 212 is operated, a foreign component-containing gaseous mixture is taken in through conduit 213 and conducted under pressure through conduits 214 and 217 which are connected by channel 216, as shown in FIG. 4, to a desiccant container 219 containing a desiccant or adsorbent bed 220. The foreign component is any undesired component and can be water vapor. The description hereinafter is written with reference to the adsorption of water vapor or moisture, for ease of illustration. It is to be understood, however, that the foreign component can be any other gaseous component such as, for example, methane, ethane, propane, octane or other hydrocarbon; acetone, methyl ethyl ketone or any other ketone; alcohol; any organic compound present in the gaseous phase; oxygen, nitrogen, helium, methane or any other gas. The gaseous mixture that is passed through the adsorbent bed can be comprised of two or more components, which components can be any of those mentioned above, or any other gaseous material. For example, the gaseous mixture can be helium plus water vapor as an impurity. The adsorbent can be any material which selectively adsorbs one or more of the above foreign components. For example, the adsorbent can be selected from silica gel, activated carbon of various types, various clays and aluminum silicates, Fuller's earth, diatomaceous earth, various metal oxides, and other adsorbent compounds and compositions well-known in the art, as well as combinations of two or more different adsorbents. The dried gas passes through conduit 221, orifice valve or flow control means 222 and conduit 223 into a first storage vessel 224. The orifice valve 222 is illustrated schematically as a combination of check valve 241 connected in parallel with variable restricted flow means 244. Gas is permitted to flow readily through check valve 241 from adsorbent chamber 220 to first storage vessel 224. Flow of gas in the reverse direction, from storage vessel 224 to container 219 is only through conduits 223 and 242, variable restricted flow means 244, and conduits 243 and 221. Thus a drop in pressure is initially obtained for flow of gas from storage vessel 224 to container 219. In this manner the adsorbent bed is slowly purged of desorbed components as described hereinbelow. From the first storage vessel, the dried gas passes through conduit 225, check valve means 226, conduit 227 and into second storage vessel 228. From the second storage vessel, the dried gas is withdrawn through conduit 229, regulator valve means 230, and conduit 231 to a region of use or requirement such as an instrument container where, for example, a substantially moisture-free atmosphere is required to insure a proper functioning of the instrument.

An alternate embodiment of this invention is to replace check valve 226 with a two-way solenoid valve (not shown) which is actuated and controlled simultaneously with the actuation and control of valve 215 and compressor 212 as described hereinbelow.

Conduit 232 connects 229, and therefore second storage vessel 228, with chamber 233 of a pressure responsive de-

vice 234, having a diaphragm 235 adapted to move in response to a pressure differential across its surface. The diaphragm is connected to one end of an activating member or push rod 236 having its other end connected to an electrical circuit switch 237. Chamber 238 of the pressure responsive device 234 is either connected to the atmosphere or evacuated. An increase in pressure in the gas in storage vessel 223 to a predetermined value causes the switch 237 to either open or close an electrical circuit, as desired. In FIG. 4 an increase in pressure would close a circuit in response to movement of the diaphragm 235. The closing of the circuit causes the activation of solenoid 239 by a source of voltage 240, to simultaneously control the movement of valve 215 and compressor 212. When the circuit is closed, the compressor 212 is stopped and valve 215 is turned to connect conduit 217 with conduit 218 by means of the new position of channel 216. The outlet of conduit 218 leads to the atmosphere or exhaust reservoir. The pressure of the gas in the desiccant container 219 is thus reduced to atmospheric or to some predetermined value or range of values, maintained in an exhaust reservoir (not shown), which reduced pressure is lower than the pressure in the first storage vessel 224 at the time of activation of switch 237, resulting in stopping of compressor 212 and turning of valve 215.

The pressure transducer shown in the drawings and described hereinabove is not to be taken by way of limitation, since any pressure transducer adapted to close or open a pair of contact points can be employed. Any suitable means well known in the art can then be employed with the pressure transducer to control the compressor 212 and valve 215.

During the charging or filling of first storage vessel 224 and second storage vessel 223, moisture is removed from the gaseous mixture by the bed of adsorbent material 220 as the gaseous mixture of air, helium or other gas passes through the desiccant container 219 and bed 220 from a first end at the junction of conduit 217 with container 219 to a second end at the junction of container 219 with conduit 221. The pressure transducer 234 is employed to activate associated circuitry of the type shown in FIG. 4 or any other actuating means which will control the operation of the compressor 212 and the valve 215. When the pressure of the gas stored in second storage vessel 223 has reached a predetermined value, the pressure transducer 234 activates the associated circuitry to cause the compressor 212 to cease operation and simultaneously causes appropriate means (not shown) to turn valve 215 so as to connect conduit 217 with conduit 218. The pressure transducer is preset to cause the shutting down of the compressor after a first cyclic period, during which the storage vessels are being filled, and the turning of valve 215, when the pressure in the second storage vessel 223, which is substantially the same as the pressure in the first storage vessel 224 during the filling operation, is equivalent to the passage of a quantity of gas of a given moisture content through the desiccant chamber 219 for a period less than required for said desiccant or adsorbent material to come to equilibrium with the adsorbed component, which in this case is water vapor. When conduit 217 is connected to conduit 218 the pressure in chamber 219 drops to atmospheric or to the pressure of the exhaust reservoir, which is maintained below that pressure in the second storage vessel 223 at which the compressor 212 is started up and conduit 217 is connected to conduit 214. Since the pressure in desiccant container 219 is reduced, the adsorbed component, which is water vapor in this example, is desorbed from the adsorbent material and flows out through conduits 217 and 218. The flow through conduit 217 is in a direction opposite to the flow of gas through this conduit when storage vessels 224 and 223 are being charged with dry gas, or foreign component-free gas. Since the pressure of the gas in desiccant container 219 is now lower than that in first storage vessel 224, the dry gas stored in first storage vessel 224 will slowly flow through the orifice valve

22, through conduit 221, then through the adsorbent bed 220 from its second end to its first end, and out through conduits 217 and 218, for a second cyclic period. Thus, the back flow of dried gas coming from the first storage vessel 224, serves as a carrier for the component desorbed from the adsorbent material 220. In this manner the adsorbent in the container 219 is reactivated. The capacity of the storage vessel 224 is such that the flow of dried gas back through the desiccant chamber 219 and out conduit 218 is sufficient to carry away an amount of the desorbed component such that the vapor pressure of the adsorbed component remaining on the desiccant after desorption and back-flow is substantially the same as or lower than the vapor pressure of the component to be adsorbed in the feed stream prior to compression. The value of the vapor pressure of the foreign adsorbed component on the adsorbing material in the adsorbent bed at the end of the second cyclic period will be but a fraction of the vapor pressure of the same component in the feed stream under compression. For example, a vapor pressure of 4 mm. of Hg of adsorbed water on silica gel when the container 219 is vented to the atmosphere at 15 p.s.i.a. through conduit 219, is but one-tenth the vapor pressure of water in compressed air fed to the adsorbent bed at 150 p.s.i.a. It will be seen that when, say, nitrogen gas is fed from a compressed storage vessel at a pressure of 150 p.s.i.a. and contains water vapor at a partial pressure of only about 0.5 mm. of Hg the vapor pressure of adsorbed water on the adsorbent bed will be only about 0.05 mm. when the pressure is reduced to an atmospheric pressure of about 15 p.s.i.a. and the adsorbent bed is flushed with dry nitrogen from the first storage vessel 224.

The adsorption and desorption cycle periods when properly adjusted are such that the heat of adsorption is conserved and available to counteract the cooling effect produced during the desorption.

One embodiment of this invention is to adjust the pressure responsive means to cause the compressor to cease operation and valve 215 to turn to exhaust the adsorbent bed when the pressure of gas collected in the second storage vessel 223 is from about one-half (0.5) to about nine tenths (.9) of the pressure at which the gaseous mixture is fed to the adsorbent bed; and to adjust the pressure responsive means to cause the compressor to start up again and the valve 215 to connect the compressor outlet with the adsorbent chamber 219 inlet when the pressure of the gas in second storage vessel 223 drops from about 10 p.s.i.a. to about 50 p.s.i.a. below the value at compressor shut down. Thus if the compressor delivers a feed stream at a pressure of about 150 p.s.i.a., the pressure responsive means can cause the compressor to be shut down at a predetermined pressure in the range of from about 135 p.s.i.a. to about 75 p.s.i.a.

A preferred embodiment of this invention is to operate the compressor to provide a feed stream at a pressure of about 130 p.s.i.a. and to set the pressure responsive means so that the compressor will shut down and valve 215 will connect the adsorbent bed with the exhaust line 218 when the gas in the second storage vessel reaches a pressure of from about 75 to 110 p.s.i.a. The compressor starts up and valve 215 turns to connect the compressor outlet conduit 214 with conduit 217 when the pressure in the second storage vessel drops from about 20 to about 40 p.s.i.a. below its value at compressor shut-down.

Another embodiment of this invention is to employ a first storage vessel which has a capacity of from about 5 percent to about 25 percent of the total capacity of the combined first and second storage vessels. An especially preferred embodiment is the use of a first storage vessel having a capacity which is about 15 percent of the capacity of the combined first and second storage vessels. The amount of adsorbent employed in the adsorbent bed is sufficient so that the bed does not come into equilibrium with the foreign component or components being adsorbed during the time period that the first and second storage

vessels are being filled with a gas from which the foreign component has been substantially removed.

When the gas is fed to the first and second storage vessels 224 and 228 through the desiccant bed 220 from a compressed gas storage vessel, the compressor may be omitted and a regular regulator valve substituted in its place in order that the gas may be supplied to the desiccant container at the required pressure. Alternatively, the compressed gas from the compressed gas storage vessel may be fed through a reduction valve or a regulating valve to the compressor. In the latter setup, when the pressure in the compressed gas storage vessel has dropped below that required to be fed to the desiccant containing chamber, the compressor serves to compress the gas to the required pressure.

As stated above, an embodiment of this invention as shown in FIG. 5, is to employ a solenoid valve 226a in place of check valve 226. In that case, when the compressor is not in operation, that is, when no pressurized gas is fed to the desiccant chamber, the solenoid valve 226a remains closed in order to prevent the flow of gas from second storage vessel 228 to the first storage vessel 224. When the compressor is started up and valve 215 turned so as to connect conduit 214 with conduit 217, the solenoid valve 226a is opened permitting an equilibration of pressures in storage vessels 224 and 228. The resulting equilibrated pressure will be higher than the compressor shut-down pressure in first storage vessel 224 since the pressure in storage vessel 228 is always maintained at a value which is above that at the outlet of conduit 213 which communicates with the first storage vessel during shut-down of the compressor or of the pressurized gas feed. As long as the compressor is in operation, the solenoid valve 226a remains open to permit free flow of gas to the second storage vessel. The purpose of equilibrating pressures in the storage vessels, and thus increasing the pressure in the first storage vessel is to provide as high a pressure as possible against which the gas coming from the desiccant container must flow. This will in turn provide for a rapid build-up of pressure in the adsorbent bed. Since more of the foreign component is removed by the adsorbent material at higher partial pressures, the use of a solenoid valve as described above to obtain a higher gaseous pressure in the adsorbent bed constitutes a preferred embodiment of this invention.

This invention also provides a method of supplying a fractional gaseous component of a gaseous mixture which is comprised of required gaseous component or components and a foreign component, to a region of requirement, utilizing an adsorbent bed having a first and a second end. The method comprises passing a feed stream of a gaseous mixture containing a foreign (undesired) component in a first flow direction from the first end to the second end of an adsorbent bed which is initially relatively free of the foreign component, at a preselected initial relatively high pressure. The adsorbent is preferentially selective for the foreign component, adsorbing the foreign component in the adsorbent bed and leaving an unadsorbed gaseous component. The unadsorbed component is discharged from the bed through a first conduit means containing a flow control means to a first storage vessel. The component is then passed from the first storage vessel to a second storage vessel through a second conduit means containing a valve means for the purpose of preventing flow of gas from the second storage vessel to the first storage vessel. The foreign component-free gaseous component is passed from said second storage vessel through a third conduit means to a region of requirement, such as an instrument container. The passage of the feed stream through the bed is discontinued when a predetermined first pressure of the required component is reached in the second storage vessel. This first pressure is lower than the high pressure at which the feed stream is fed to the adsorbent bed. The foreign component is then desorbed from the adsorbent bed and the desorbed

component is passed out of the first end of the bed in a second flow direction opposite to the above mentioned first flow direction. The required or foreign component-free gas is then passed from the first storage vessel through the first conduit means and through the adsorbent bed in the second flow direction. Thereafter the passing of the feed stream through the bed is resumed when a second pressure of the gaseous component in the second storage vessel is reached. The second pressure is lower than the first pressure and is obtained when an amount of the gas stored in the second storage vessel has been used up in a required region sufficient to drop the pressure to the point that the compressor is reactivated and a feed stream of the gaseous mixture is again passed through the adsorbent bed. Alternatively, a gaseous mixture is fed from a compressed storage vessel instead of utilizing a compressor.

The periods during which certain events take place in the above described method have been given labels such as "first cyclic period" and "second cyclic period." The "first cyclic period" is the time period during which the compressed gas is fed to the adsorbent bed and the first and second storage vessels are being filled. The "second cyclic period" is the time period during which the foreign component is desorbed from the adsorbent bed material and the gas from the first storage vessel is passed through the orifice means 222, through the bed 220, conduits 217 and 218, to exhaust. There is a third period which overlaps the second cyclic period and this third period extends from the end of one "first cyclic period" to the beginning of the next first cyclic period. This third period includes all of the "second cyclic period" plus all the additional time after the end of the "second cyclic period" when the gas from the second storage vessel continues to be supplied to a region of requirement and during which time the compressor continues to remain inoperative, i.e., no gas under pressure is fed to the adsorbent bed.

The great advantage of the apparatus and process of this invention is that the compressor is operated, and therefore, the compressed gas is supplied to the adsorbent bed, only at relatively infrequent intervals, on demand. There is no waste of processed or purified gas, making this invention economically more attractive than prior art methods.

The process of this invention is more clearly illustrated by the following examples.

Example I

The apparatus of FIG. 4 is employed to provide dry air to an instrument container. The ratio of the capacity of the second storage vessel 228 to the capacity of the first storage vessel 224 is substantially 10-to-1. The ratio of the combined storage volume of vessels 224 and 228 to the volume of the adsorbent container 219 is substantially 70-to-1. A body of silica gel is contained in the container 219. Air is fed at a pressure of 150 p.s.i.a. by the compressor 212 to the silica gel adsorbent bed through the pressure control valve 222 to the storage vessels 224 and 228. The moisture content in the compressed air is equivalent to a partial pressure of water vapor of about 15 mm. of Hg. When the pressure in the second storage vessel 228 reaches a value of 135 p.s.i.a. the pressure transducer acts to activate solenoid 239 which in turn causes the shutting down of the compressor 212 and simultaneously causes valve 215 to be turned so as to connect conduit 217 with outlet conduit 218. The water vapor that is adsorbed by the silica gel in the adsorbent bed during the feeding cyclic period, is desorbed and flows out through conduits 217 and 218. The dried air from the first storage vessel 224 slowly passes through the orifice valve 222, through the desiccant bed in a direction opposite to the original feed stream flow. As the dried gas flows through the desiccant bed it serves as a carrier for the desorbed moisture and carries it out through conduit 218. The dry air stored in vessel 228 contains

water vapor at a partial pressure of less than 1 mm. of Hg and is passed through regulator valve 230 to an instrument container (not shown) where it is employed to keep the working mechanism of the instrument in a dry atmosphere so as to prevent corrosion and malfunctioning of the instrument parts. When the pressure in the second storage vessel 228 reaches a value of 125 p.s.i.a., the solenoid 239 is deactivated, the valve 215 is turned to again connect conduits 217 with 214, and the compressor is started up to resume providing a feed stream of air at 150 p.s.i.a. The regulator valve is adjusted so that the time required for the pressure to drop from 135 p.s.i.a. to 125 p.s.i.a. is about four times as long as the time required for the compressor to bring the pressure in the storage vessels up to 135 p.s.i.a. Thus, the period for filling the storage vessel is only one-fifth as long as the total period between successive initiations of the feed stream supply to the adsorbent bed.

Example II

The procedure of Example I is repeated using a feed stream of nitrogen gas at a compressor outlet pressure of substantially 150 p.s.i.a., containing a mixture of ethane and ethylene in substantially equal proportions at a partial pressure of about 5 mm. of Hg. In this example, the ratio of the capacity of the second storage vessel to the capacity of the first storage vessel is substantially 4-to-1. The ratio of the combined storage volume of the two storage vessels to the volume of the adsorbent container is substantially 30-to-1. The feeding of the gas through the adsorbent bed is discontinued when the pressure reaches 75 p.s.i.a. in the second storage vessel and resumed when the pressure drops to 25 p.s.i.a. The adsorbent employed in this instant is a 4 A. molecular sieve. The molecular sieve contains sodium aluminosilicate having a uniform pore size of about 4 Angstrom units and is made by mixing an aqueous solution of an alkaline metal silicate and sodium aluminate in such proportions that the ratio of alumina to silica in the mixture is from about 1:3 to about 1:2. The processed nitrogen stored in the vessels contains an amount of ethane and ethylene having a partial pressure of less than about 0.3 mm.

Example III

The procedure of Example I is followed with the modification that carbon dioxide containing about 1 percent oxygen is passed through an adsorbent bed made up of a 4 A. molecular sieve. The gas is fed from a CO₂ storage vessel through a reduction valve directly to conduit 214 without the use of the compressor, at a pressure of 100 p.s.i.a. The feed stream of CO₂ gas is discontinued when the pressure in the second storage vessel reaches 80 p.s.i.a. and resumed when it drops to 50 p.s.i.a. The processed CO₂ stored in the vessels contains less than 0.05 percent of oxygen.

Example IV

The procedure of Example I is repeated with the modification that impure helium gas containing water vapor at a partial pressure of 0.8 mm. in a feed stream at 130 p.s.i.a., is fed from a cylinder through a reduction valve without the use of a compressor. The feeding is interrupted when a pressure of 75 p.s.i.a. is reached in the storage vessels, and is resumed when the pressure drops to 35 p.s.i.a. Silica gel is employed as a desiccant. In this example, the ratio of the capacity of the second storage vessel to the capacity of the first storage vessel is substantially 7-to-1. The ratio of the combined storage volume of the two storage vessels to the volume of the adsorbent container is substantially 57-to-1. The dry gas in the storage vessel contains water vapor at a partial pressure less than 0.05 mm. The regulator valve is set so as to provide for a flow of gas to the instrument container such that the period during which the pressurized impure helium is fed to the system is only about one-

tenth of the total period between the beginning of consecutive feeding periods.

The procedure of Example IV is followed in removing water vapor from Freon gas.

Example V

The procedure of Example IV is repeated with the modification that commercial nitrogen gas containing water vapor at a partial pressure of about 0.2 mm. at a feed stream pressure of 110 p.s.i.a. is fed with the aid of a compressor through a desiccant bed of silica gel to the storage vessels. The adsorbent bed container is cylindrical in shape and has a ratio of diameter to length of about 1-to-6. The supply of nitrogen gas is discontinued when the pressure in the second storage vessel reaches 60 p.s.i.a. and resumed again when the pressure drops to 40 p.s.i.a. The dry gas in storage vessels contains a partial pressure of water vapor less than 0.01 mm. of Hg. The regulator valve 230 is adjusted to provide a flow of dried nitrogen to the place of requirement such that the compressor operates one-third of the time between successive initiations of commercial nitrogen gas supply through the desiccant bed.

Other cylindrical adsorbent containers are also used wherein the ratio of the diameter to length varies from about 1:4 to about 1:10. The shape of the container is not limiting and containers in the shape of a parallelepiped and many other shapes are used.

Example VI

The procedure of Example IV is repeated with the modification that the apparatus of FIG. 4 contains a two-way solenoid valve 226a, as shown in FIG. 5, in place of check valve 226 in the conduit line connecting the first storage vessel 224 to the second storage vessel 228. This solenoid valve is activated as described hereinabove to provide flow of gas from the first storage vessel to the second storage vessel during the period that the feed stream is passed through the adsorbent bed and the storage vessels are being filled. When the passage of the feed stream is discontinued, the solenoid valve is closed to prevent the flow of gas from the second storage vessel back to the first storage vessel. Thereafter, when the passage of the feed stream is again resumed, the solenoid valve is reopened permitting the gas remaining in the second storage vessel to flow back to the first storage vessel and on to the adsorbent chamber. Back pressure is thus provided against the forward flow of unadsorbed gaseous components coming from the feed stream. This provides for a rapid build-up of pressure in the adsorbent bed and a more efficient operation of the adsorbent material. A lower partial pressure of water vapor is found in the gas in these storage vessels upon the use of the solenoid valve as described in this example than in the case of Example I.

In like manner, the procedures of Examples I-V are repeated employing a solenoid valve in place of check valve 226 to provide a more efficient removal of the foreign component by the adsorbent bed.

Although this invention has been described in detail above, this description is to be taken by way of example only and not by limitation, the spirit and scope being limited only by the appended claim.

We claim:

A method of supplying a fractionated gaseous component of a gaseous mixture comprising a gaseous component and a foreign component to a region of requirement utilizing an adsorbent bed having a first end and a second end, comprising passing a feed stream of a gaseous mixture containing a gaseous foreign component in a first flow direction from said first end to said second end of said adsorbent bed initially relatively free of said foreign component at a preselected initial relatively high pressure, said adsorbent being preferentially selective for said foreign component, adsorbing said foreign component in said adsorbent bed and leaving an unadsorbed

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gaseous component, discharging said unadsorbed gaseous component from said bed through a first conduit means containing a flow control means to a first storage vessel, passing said unadsorbed gaseous component from said first storage vessel to a second storage vessel through a second conduit means containing a valve means to provide for a flow of gas from said first storage vessel to said second storage vessel and alternately from said second storage vessel to said first storage vessel as required, and passing said component from said second storage vessel through a third conduit means to a region of requirement, discontinuing the passing of said feed stream through said bed at a predetermined first pressure of said unadsorbed gaseous component in said second storage vessel wherein said first pressure is lower than said relatively high pressure, preventing the flow of gas from said second storage vessel to said first storage vessel, desorbing said foreign component from said adsorbent bed and passing said desorbed component from said first end of said bed in a second flow direction opposite to said first flow direction and passing said unadsorbed gaseous component from said first storage vessel through said first

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conduit means and through said bed in said second flow direction, resuming the passing of said feed stream through said bed upon attaining a second pressure of said component in said second storage vessel which is lower than said first pressure and simultaneously permitting the gas to flow from said second storage vessel to said first storage vessel and intermittently back-flowing said gaseous component from said first storage vessel through said adsorbent bed.

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