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Leonard

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[54] **OUTPUT CONTROL FOR STEAM HEATED HEAT EXCHANGER**

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Related U.S. Application Data

[62] Division of Ser. No. 789,162, Jan. 6, 1969, Pat. No. 3,587,726.

[52] **U.S. Cl.** **55/21,** 55/163

[51] **Int. Cl.** **B01d 53/04**

[58] **Field of Search** 55/21, 33, 163, 179

[56] **References Cited**

UNITED STATES PATENTS

3,282,027	11/1966	Johnson et al.	55/163
3,080,219	3/1963	Harvey	55/21
3,230,688	1/1966	Kitchen et al.	55/163
3,540,188	11/1970	Barrere et al.	55/163
3,208,230	9/1965	Fourroux	55/67

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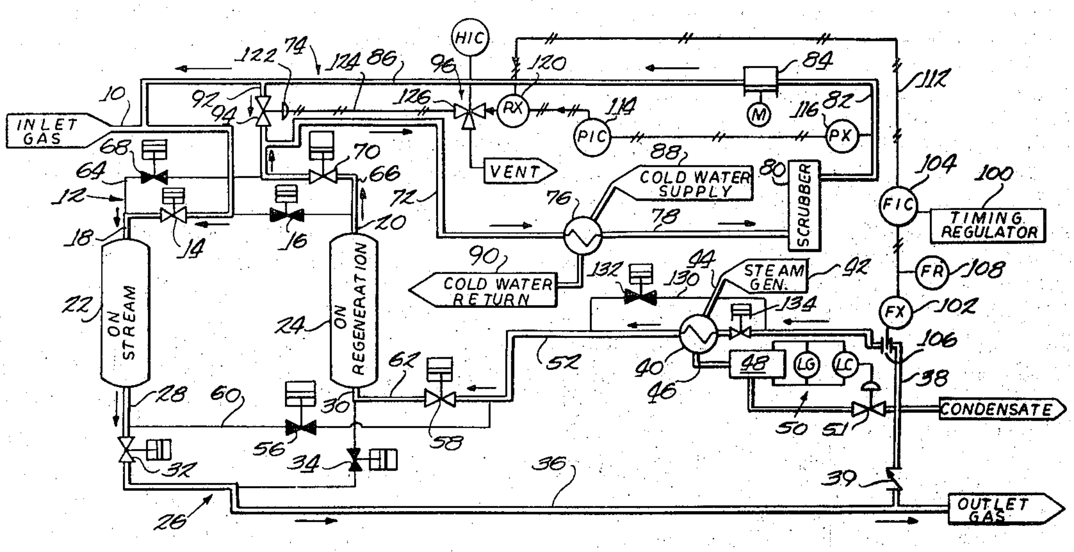
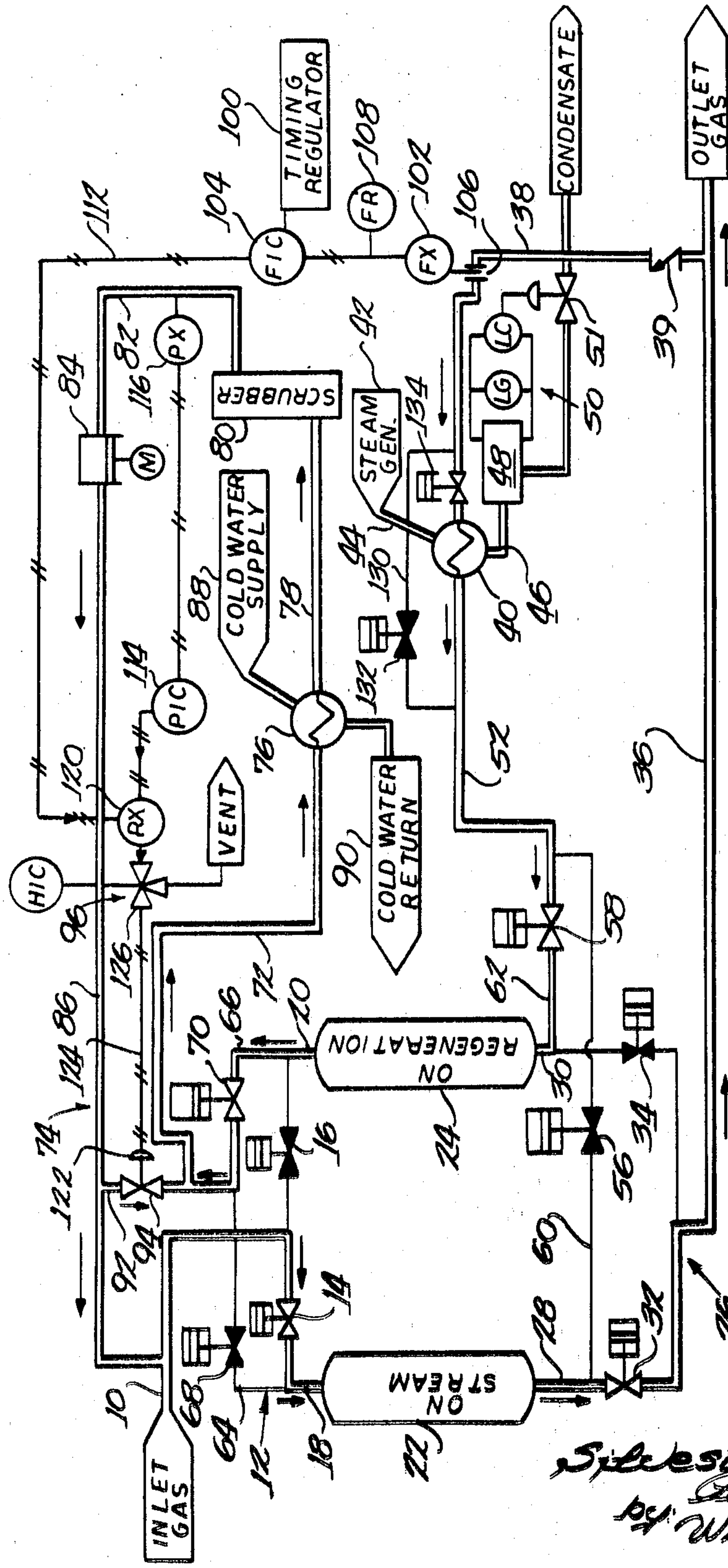
[57] **ABSTRACT**

A multiple tower gas dehydration system is disclosed wherein the regeneration gas is heated in a steam heated heat exchanger, with the heat exchanger in open communication with a steam generator. After passage through the regenerating tower, the regeneration gas passes through dehydrating components, then through a continuously operated motor-driven compressor, and is returned to the wet gas input. A bypass including a variable control valve is connected between the return line to the wet gas line and the regenerating gas outlet from the towers to provide a recirculating loop through the regeneration gas dehydrating components and the compressor. The variable control valve is automatically selectively controlled in response to either the pressure in the recirculating loop or the differential between a timed flow regulator signal and the rate of flow of the regenerating gas through the heat exchanger, whereby this control valve provides regulated control over the flow of regeneration gas for regulated gradual change in demand upon the steam generator.

21 Claims, 1 Drawing Figure





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OUTPUT CONTROL FOR STEAM HEATED HEAT EXCHANGER

This is a division of my copending application Ser. No. 789,162, filed Jan. 6, 1969 (now U.S. Pat. No. 3,587,726).

This invention relates to apparatus for controlling the output of a steam generator. More particularly this invention pertains to apparatus for avoiding sudden substantial changes in demand upon the steam generator in a gas dehydrating system which utilizes steam for heating the regeneration gas flow.

Various systems are known for dehydrating gas wherein a plurality of desiccant beds in dehydrating towers are utilized sequentially, with arrangements for circulating a heated gas through the beds for regeneration purposes. The operating cycle of such systems normally results in intermittent demand upon the regeneration gas system. Where steam is utilized as the heating medium for the regeneration gas, the result may be sudden high demands upon the steam generator system. This may cause water to be carried out from the generator with the steam, particularly in a system wherein the steam flows freely from the steam generator to the heat exchanger in response to demand, without control means in the steam supply line. It is desirable that the demand for steam from the steam generator be controlled to avoid such sudden high steam demands. It is also desirable that the demand for steam from the steam generator be gradually decreased to prevent surging in the boiler firing rate.

It is an object of this invention to overcome the problems indicated above.

It is another object of this invention to provide an improved control arrangement for a steam heated heat exchanger system.

It is a further object of this invention to provide improved control over the flow of regenerating gas in a natural gas dehydrator system.

Another object of this invention is to provide a gas dehydrator system having a steam heated heat exchanger in the regeneration line with improved control over the changes in demand upon the steam generator.

Further and additional objects and advantages will appear from the description, accompanying drawings and appended claims.

In carrying out this invention in one illustrative form, a natural gas dehydration system is provided including a plurality of dehydrator towers each containing a desiccant bed, with a control system for cycling heated regeneration gas through one tower while the main flow stream being dehydrated is passed through another of such towers. The regeneration gas passes through a steam heated heat exchanger, through the regenerating tower, which contains dehydrating components such as adsorbents, and through a motor-driven compressor. A recirculating line is provided for recirculating the regeneration gas through the compressor, and a variable valve is interposed in the recirculating line, with control means for gradually adjusting said variable valve to avoid sudden increases or decreases in flow of the regeneration gas through the heat exchanger.

For a more complete understanding of this invention, reference should now be had to the embodiment illustrated in the accompanying drawings and described below, by way of example of the invention.

In the drawing, the single FIGURE comprises a diagrammatic representation of a two-tower gas dehydrator system embodying teachings of this invention.

In the drawing, conduit **10** is the input conduit for supplying natural gas to the illustrated system for dehydration. It will be appreciated that the input gas may be subjected to pretreatment as desired, e.g., by being passed through a gas scrubber (not shown) to extract mechanically entrained water, hydrocarbons or the like.

The conduit **10** leads to a manifold **12** which includes valves **14** and **16** and inlet conduits **18** and **20** for selectively directing the gas to adsorbing towers **22** and **24.** A manifold **26** including conduits **28** and **30,** and valves **32** and **34,** connects the towers **22** and **24** with the outlet conduit **36** which may be connected to further processing components as desired.

The towers or vessels **22** and **24** are provided with desiccant beds for adsorbent removal of water, hydrocarbons or the like from the gas being processed. It will be appreciated that while one of these towers is connected between conduits **10** and **36** in the main flow line for dehydrating the gas being processed, the other tower is subjected to appropriate treatment for regenerating and preparing the desiccant for further "on line" dehydrating use.

In the illustration it is assumed that tower **22** is in use for dehydrating the main stream of gas and tower **24** is being regenerated, as indicated by the labels on the towers, the open lines, the arrows, and the depictions of the various valves.

The regeneration system utilizes gas split-off from the main outlet conduit **36** through conduit **38** and one-way valve **39.** Conduit **38** leads to a heater **40,** comprising a steam heated heat exchanger. A steam generator for supplying steam to heat exchanger **40** is illustrated schematically at **42** and may comprise a conventional boiler steam generating unit which is connected to the heat exchanger by an open conduit **44.** The rate of heat removal from the steam, and the attendant rate of condensation in the heat exchanger, determines the steam flow rate from the generator **42** to the heater **40.** The condensate from the steam used in the heat exchanger passes through conduit **46** into a condensate accumulator **48.** Appropriate liquid level controls **50** operate a control valve **51** for exhausting the condensate.

A conduit **52** leads from the heater **40** to the manifold **26.** Manifold **26** includes valves **56** and **58** which are connected to the line **52** and to conduits **60** and **62** which are connected to the conduits **28** and **30,** for selevtively directing the regenerating gas to the towers **22** and **24.** The heated regenerating gas passes upward through the tower "on regeneration" (tower **24** in the drawing) to the manifold **12.** In passing through the adsorbent in the tower the heated gas displaces the adsorbed components from the desiccant bed therein to reactivate this bed for subsequent "on line" dehydrating usage.

In the manifold **12,** conduits **64** and **66** connect conduits **18** and **20** to valves **68** and **70** which are in communication with conduit **72** of a regeneration gas treatment line indicated generally at **74.** This regeneration gas treatment line includes a cooler or condenser **76,** conduit **78,** a separator or scrubber **80,** conduit **82,** a motor driven compressor **84,** and conduit **86** which is connected to the input conduit **10.** The condenser **76** and scrubber **80** function in a conventional manner to condense and remove by separation the stripped materials, e.g., water and hydrocarbons, carried from the generating tower by the regeneration gas. Condenser **76** may be a heat exchanger supplied with a cold water coolant from a supply **88** with exhaust to **90**, as illustrated, or other suitable cooling means. The motor-driven compressor **84** is a continuously operated, constant rate compressor, and provides adequate pressure differential to impel the regeneration gas through the regeneration system in the manner described.

Control of the rate of flow of the regenerating gas is obtained by providing a bypass line **92** connecting conduit **86** to conduit **72**, with a variable control valve **94** in this line for controlled recirculation of regeneration gas through a loop circuit comprising conduits and components **72, 76, 78, 80, 82, 84, 86, 92** and **94.**

Valve **94** is an appropriate valve for remote positional control, and is positioned in response to controls **96**. The position of this valve is determined from two inputs derived from two system conditions and one external control. One of these inputs is the differential between a regulated variable set point, supplied by a timing regulator **100**, and a signal representing the flow rate of the regeneration gas through conduit **38**. The other input represents the pressure in the conduit **82.**

The apparatus for providing the first noted input to controls **96** comprises a flow rate transducer **102**, the regulator **100** and a flow controller **104**. The regulator **100** provides a time-controlled variable set-point signal to the controller **104**. Transducer **102** senses the pressure differential across an orifice **106** in line **38** and provides a signal to the controller **104** corresponding to the flow rate in the conduit **38**. The controller **104** compares the signals received from regulator **100** and transducer **102** and provides an output control signal related to the differential between these input signals. In the illustrated system, utilizing pneumatic controls, regulator **100** may include an appropriate cam driven by a timing motor for slowing opening a valve (not shown) to provide a slowly increasing pressure signal to controller **104** upon initiation of a regenerating cycle, and a decreasing signal to controller **104** after the adsorbent has been stripped. Transducer **102** provides a pressure signal representative of the flow rate in conduit **38**. Controller **104** serves as a subtractor relay in that it transmits a pressure signal through conduit **112**, to controls **96**, which is related to the differential between the pressure inputs from the regulator **100** and the transducer **102**. If the pressure input from regulator **100** exceeds the transducer **102** output, the signal transmitted by controller **104** will increase in accordance with the differential therebetween.

A flow recorder **108** may be connected with transducer **102** as desired.

The second input to controls **96** is provided by a pressure controller **114**. Controller **114** receives a signal from pressure transducer **116** which is representative of the pressure in conduit **82**. In the illustrated system, the pressure signal transmitted from controller **114** to controls **96**, through line **118**, is related to the pressure in conduit **82.**

Controls **96** effectively select between the two input signals thereto from controllers **104** and **114**, and control the position of valve **94** in accordance with the selected signal. In the illustrated system, a low select relay **120** selects the lower of the two input pressure signals from controls **104** and **114** and positions valve **94** in proportion to the lower signal received, by appropriate positioning of a diaphragm-type motor **122**. As the effective signal received by relay **120** increases, the pressure signal to motor **122** through line **124** is increased to adjust the valve **94** toward its closed position. Conversely, as the effective signal to relay **120** decreases, the valve **94** is adjusted towards its open position.

A control valve **126** is provided to hand regulate pneumatic pressure for operating the motor **122** to position valve **94** when desired.

The controller **114** transmits a signal which is higher than the signal from controller **104** under normal conditions of operation. However, the signal transmitted by controller **114** will be lower than the signal from controller **104** when controller **104** is set for flow through line **38** and the flow through line **38** is decreased abnormally below the set point of controller **104**, e.g., as a result of malfunction of some part of the regeneration system. Thus, under such conditions, relay **120** of controls **96** selects the lower signal from controller **114** and thereby regulates the recirculation of gas through the closed loop comprising bypass **92** and the line **74.**

In operation, the illustrated system normally will provide a pressure change, i.e., a pressure drop, throughout the system in the direction of flow, except across compressor **84**. That is, there will be a pressure drop across each component from the inlet conduit **10** to the outlet of conduit **36**, and from the valve **39** to the inlet to compressor **84**. The compressor provides an adequate pressure increase to provide return flow therefrom into inlet conduit **10**. Thereby, it will be appreciated that the pressure in conduit **86** normally is substantially above the pressure in conduit **72**, and there is a corresponding pressure drop across valve **94.**

When the desiccant in the "on line" dehydrator becomes spent, appropriate controls reposition the various valves in accordance with the operating cycle to switch the flow streams between the dehydrator towers, and then start the regulator **100**. As a new regeneration cycle is initiated, the regulator **100** provides a slowly changing signal to controller **104** which in turn transmits a slowly changing signal to the controls **96** in accordance with the differential between the inputs from regulator **100** and transducer **102**. Thus, at the beginning of regeneration of the adsorbent in a tower, the regulator **100** will begin to increase the setting of controller **104** which will cause the pressure transmitted to relay **120** to be increased. This in turn will cause valve **94** to begin to close to initiate the flow through line **38**, and thereby will cause the pressure from transmitter **102** to controller **104** to follow the setting of controller **104**. Thereafter, the controls **96** gradually adjust valve **94** toward a closed position in response to the slowly increasing signal generated by controller **104** as the set-point from regulator **100** is slowly increased.

Since the compressor operates at a substantially uniform rate, the closing adjustment of valve **94** causes a drop in the pressure in conduit **82**, and hence in conduit **72**, which causes the regenerating gas to flow through the conduit **38**, the heater **40** and the tower being regenerated. The drop in pressure in conduit **82** decreases the input signal from controller **114** to relay **120**, but not lower than the pressure signal from controller **104**. Thereby, controller **104** continues to provide a lower signal than controller **114**, and controller **104** remains in control of valve **94**.

Accordingly, continued gradual increase of the set-point to controller **104** by regulator **100** further increases the differential over the actual flow signal from transducer **102** and causes further adjustment of valve **94** toward a closed position. This further decreases the recirculating flow through bypass **92**, and causes attendant continued gradual increase in the rate of regenerating flow through heater **40**. As the rate of flow of regenerating gas through heater **40** thus is slowly increased, the rate of condensation of steam in heat exchanger **40** will be similarly increased for concomitant gradual increase of demand upon the steam generator **42**, thereby gradually increasing the steam flow rate until the generator boiler is generating at the maximum required rate.

Since the movement of valve **94** in response to controller **104** is dependent upon the differential between the signals from regulator **100** and transducer **102**, the flow rate through conduit **38** will continue to lag the increasing set-point of regulator **100**. Accordingly, the maximum set-point of regulator **100** is such that an equilibrium condition is established wherein the differential between the two signals to controller **104** is adequate to provide an input to controls **96** appropriate to maintain valve **94** in the partially closed position appropriate to sustain the maximum desired regenerating flow.

When the adsorbent in a tower has been regenerated, the regulator **100** will slowly reduce the set-point of controller **104** to zero. Upon such decrease of the set-point from regulator **100**, the differential between this set-point and the flow signal from transducer **102** will slowly decrease to slowly open valve **94**, and the regeneration flow rate will decrease accordingly. With the set-point of controller **104** at zero, controller **104** will transmit a signal of zero pressure to relay **120**. Relay **120** will transmit a signal of zero pressure to motor **122** which causes valve **94** to be fully open.

Thus, the described apparatus and method conveniently and economically provide accurate control over the flow of the regenerating gas, with attendant control of the flow through the heat exchanger and thus of the changes in demand upon the steam generator equipment. The varying load upon the heat exchanger is accommodated and the attandant changes in the rate of flow of steam from the steam generator to the heat exchanger are obtained under the desired control without the use of valves in the steam line.

A line **130**, and control valves **132** and **134**, may be provided for bypassing heater **40** to direct dry gas through a tower to cool the desiccant bed therein subsequent to regeneration and prior to return to "on line" use. The described regeneration control system may be programmed to control such cooling flow as desired.

The various valves for controlling the cycling of the illustrated system may be positioned by any suitable means, one example being the use of piston motor valves, as indicated in the drawing, with the piston motors being operated by a pneumatic control system. Further processing equipment may be included in line **36**, or downstream therefrom, as desired.

It will be appreciated that an improved system and method have been provided which meet the aforestated objects.

While a particular embodiment of this invention has been shown, it will be understood, of course, that the invention is not limited thereto since modifications may be made by those skilled in the art, particularly in light of the foregoing teachings. Therefore, it is contemplated by the appended claims to cover any such modifications as incorporate those features which may be said to constitute the essential features of these improvements, within the true spirit and scope of the invention.

I claim:

1. In cyclic adsorption apparatus including a gas supply line, a plurality of vessels each containing desiccant material for removing one or more components from wet gas and being cyclically connectable to said gas supply line, a dry gas output line, a regenerating gas system cyclically connectable to selectively include each one of said vessels to pass regenerating gas therethrough for regenerating such desiccant material, and means in said regenerating gas system for circulating regenerating gas through said system, the improvement comprising recirculating conduit means having one end connected in said regenerating gas system between said vessels and said circulating means and having its opposite end connected in said system on the side of said circulating means opposite said first end and defining with a portion of said regenerating gas system a recirculating circuit including said circulating means and said recirculation conduit means and excluding said vessels for recirculating flow of gas through said recirculating circuit without such recirculating flow passing through said vessels, variable flow control means for controlling the rate of flow through said recirculating conduit means, and means for adjusting said flow control means to regulate the rate of flow of such gas through said recirculating conduit means and thereby regulate the rate of flow of regenerating gas through the one of said vessels on regeneration and through the remainder of said regenerating gas system external to said recirculating circuit.

2. Cyclic adsorption apparatus as in claim **1** including a heat exchanger in said regenerating gas system, and steam generator means connected to said heat exchanger for supplying steam thereto to heat such regenerating gas, said heat exchanger being external to said recirculating circuit, whereby adjustment of said flow control means regulates the rate of flow of regenerating gas through said heat exchanger and thereby controls the demand upon said steam generator.

3. Cyclic adsorption apparatus as in claim **1** wherein said circulating means and said recirculating circuit are on the downstream side of said vessels in said regenerating system.

4. Cyclic adsorption apparatus as in claim **1** including regenerating gas dehydrating components in said recirculating circuit.

5. Cyclic adsorption apparatus as in claim **2** including conduit means connecting said heat exchanger to said dry gas output line and to one of said vessels in regenerating cycle for directing dry regenerating gas through said heat exchanger to such vessel, and said recirculating circuit being on the downstream side of such regenerating vessel in said regenerating gas system.

6. Cyclic adsorption apparatus as in claim **5** including means in said recirculating circuit for dehydrating such regenerating gas, a return line from said recirculating circuit to said gas supply line, said recirculating conduit means communicating between said return line and the input connection to said regeneration gas dehydrating means.

7. Cyclic adsorption apparatus as in claim 1 wherein said adjusting means includes a timing regulator and provides control of said flow control means which is responsive to said timing regulator and to the rate of flow of regenerating gas in said regenerating gas system external to said recirculating circuit.

8. Cyclic adsorption apparatus as in claim 1 wherein said circulating means circulates such gas therethrough at a substantially constant rate.

9. Cyclic adsorption apparatus as in claim 1 including a heat exchanger in said regenerating gas system external to said recirculating circuit.

10. Cyclic adsorption apparatus including a wet gas supply line, a dry gas output line, a plurality of vessels each containing desiccant material for removing one or more components from wet gas and being cyclically connectable to said supply and output lines, and a regenerating gas system; said regenerating gas system including: an input line connected to said dry gas output line and cyclically connectable to said vessels; a heat exchanger in said input line; a steam generator connected to said heat exchanger for supplying steam thereto in response to demand for heating the regenerating gas; a return line cyclically connectable to said vessels and connected to said supply line for flow of regenerating gas from said vessels to said supply line; means in said return line for dehydrating said regenerating gas; means in said return line for circulating regenerating gas through said system and through one of said vessels connected therewith; recirculating conduit means on the downstream side of said vessels and connected between the upstream and downstream sides of said dehydrating and circulating means and thereby completing a recirculating circuit including said dehydrating means, said circulating means and said recirculating conduit means and excluding said vessels and said heat exchanger for recirculating flow of gas through said recirculating circuit without such recirculating flow passing through said vessels or said heat exchanger; variable flow control means for controlling the rate of flow through said recirculating conduit means; and means for adjusting said flow control means to regulate the rate of flow of such gas through said recirculating conduit means and thereby regulate the rate of flow of regenerating gas through the one of said vessels on regeneration and through said heat exchanger.

11. Cyclic adsorption apparatus as in claim 10 wherein said adjusting means includes a timing regulator and provides control of said flow control means which is responsive to said timing regulator and to the rate of flow of regenerating gas in said regenerating gas system external to said recirculation circuit.

12. Cyclic adsorption apparatus as in claim 11 wherein said adjusting means includes a control responsive to the pressure in said recirculating circuit.

13. Cyclic adsorption apparatus as in claim 12 wherein said adjusting means includes means providing a first signal proportional to the differential between the input of the timing regulator and the flow rate in said system external to said recirculating circuit, means providing a second signal proportional to the pressure in said recirculating circuit, and means for providing a flow reducing signal to said flow control means in accordance with the lower of said first and second signals.

14. In cyclic adsorption apparatus including a gas supply line, a plurality of vessels each containing desiccant material for removing one or more components from wet gas and being cyclically connectable to said gas supply line, a dry gas output line, a regenerating gas system cyclically connectable to selectively include each one of said vessels to pass regenerating gas therethrough for regenerating such desiccant material, and means in said regenerating gas system for circulating regenerating gas through said system, the improvement comprising said regenerating gas system including a heat exchanger, steam generator means connected to said heat exchanger for supplying steam thereto to heat such regenerating gas, recirculating conduit means having one end connected in said regenerating gas system between said heat exchanger and said circulating means and having its opposite end connected in said system on the side of said circulating means opposite said first end and defining with a portion of said regenerating gas system a recirculating circuit including said circulating means and said recirculation conduit means and excluding said heat exchanger for recirculating flow of gas through said recirculating circuit without such recirculating flow passing through said heat exchanger, variable flow control means for controlling the rate of flow through said recirculating conduit means, and means for adjusting said flow control means to regulate the rate of flow of such gas through said recirculating conduit means and thereby regulate the rate of flow of regenerating gas through said heat exchanger and through the remainder of said regenerating gas system external to said recirculating circuit.

15. Cyclic adsorption apparatus as in claim 14 wherein said adjusting means includes a timing regulator and provides control of said flow control means which is responsive to said timing regulator and to the rate of flow of regenerating gas in said regenerating gas system external to said recirculating circuit.

16. A cyclic adsorption gas dehydrating process utilizing a plurality of vessels each containing a desiccant material for removing one or more components from wet gas, a wet gas input to said vessels, a dry gas output from said vessels, and fluid circulating means for causing regeneration gas to flow through a related regeneration gas system which includes said vessels, comprising withdrawing gas for regeneration from said dry gas output, heating such dry regeneration gas, cyclically passing such heated regeneration gas through each of said vessels for regenerating said desiccant material therein, and subsequently returning said regeneration gas to said wet gas input, passing such regeneration gas through said circulating means at a substantially constant rate between such withdrawal thereof from said output and return thereof to said input to provide the described flow of such regeneration gas, cyclically terminating and re-initiating flow of such regeneration gas through at least one section of such regeneration system in conjunction with changing of the regeneration cycle from vessel to vessel, and controlling the flow rate and the rate of change in the flow of such regeneration gas through such section during such terminating and re-initiating of such flow therethrough by recirculating a portion of such gas through said fluid circulating means without passage of such recirculated gas through said section and varying the portion of said regeneration gas being so recirculated in accordance with a predetermined time regulated input.

17. A process as in claim 16 wherein such section of such system through which the rate of flow and rate of change of flow is so controlled includes such vessels.

18. A process as in claim 17 wherein such section of such system through which the rate of flow and rate of change of flow is so controlled includes a heat exchanger for said heating of such regeneration gas.

19. A process as in claim 16, wherein such section of such system through which the rate of flow and rate of change of flow is so controlled includes a heat exchanger for said heating of such regeneration gas.

20. A process as in claim 16 including providing a signal representative of the rate of flow of regeneration gas through said section and providing a time regulated signal, comparing said signals, and varying the portion of said regeneration gas being so recirculated in accordance with the differential between said signals.

21. A process as in claim 20 including controlling the portion of said regeneration gas being so recirculated and thereby maintaining the pressure of the recirculating gas at a predetermined value to preclude flow of regeneration gas through said section during a part of the operating cycle of said gas regeneration system.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,766,713 Dated October 23, 1973

Inventor(s) SILVESTER C. LEONARD

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Title page and Column 1, lines 1 and 2, change the title to read "Control of Regeneration in Cyclic Adsorptic System". Column 5, line 48, "attandant" should read -- attendant --.

Signed and sealed this 2nd day of April 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents