July 31, 1956 P. W. CORNELL ET AL 2,757,067

METHOD AND APPARATUS FOR GAS STORAGE

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2 Sheets-Sheet 1

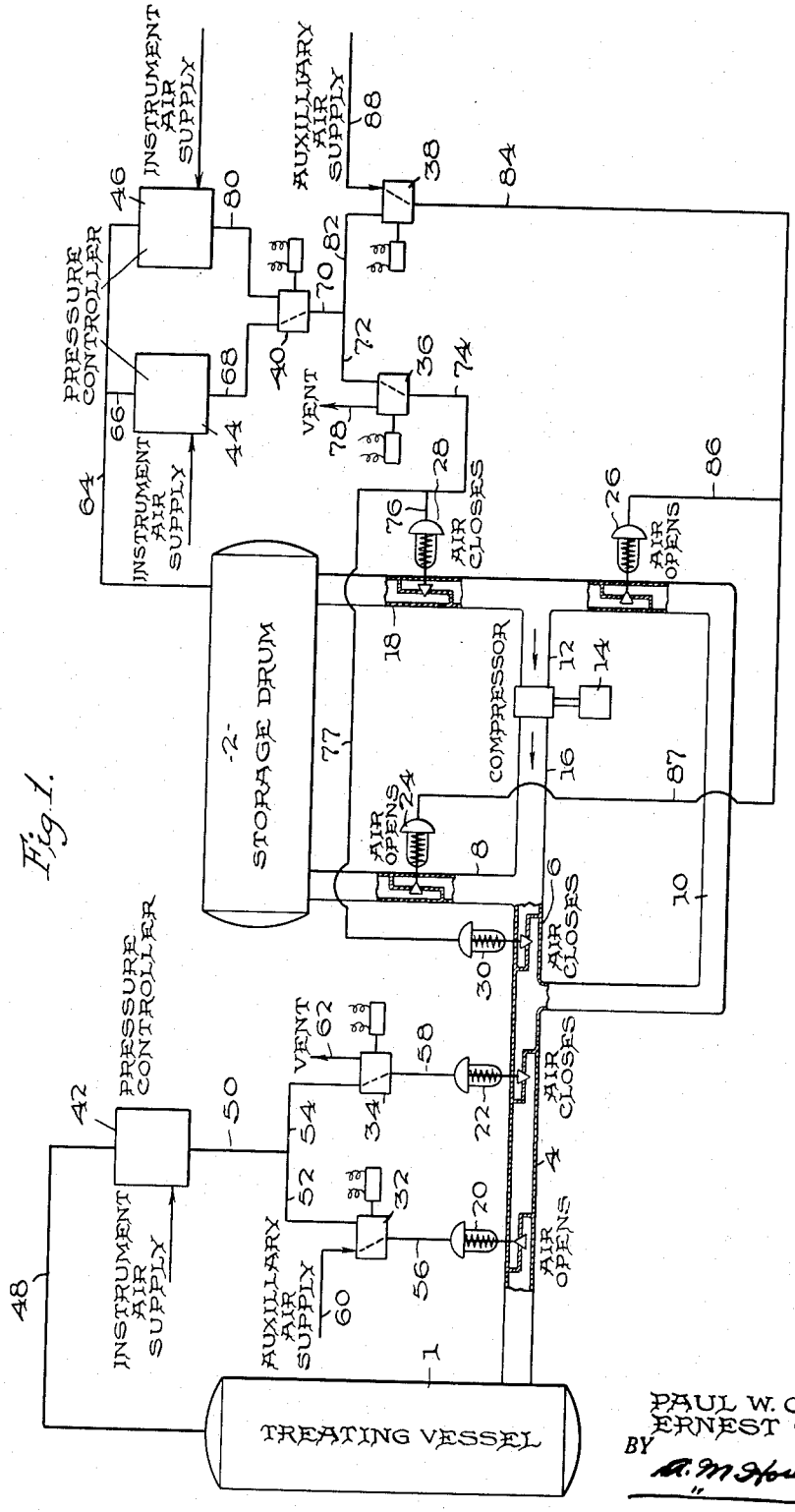


Fig. 1.

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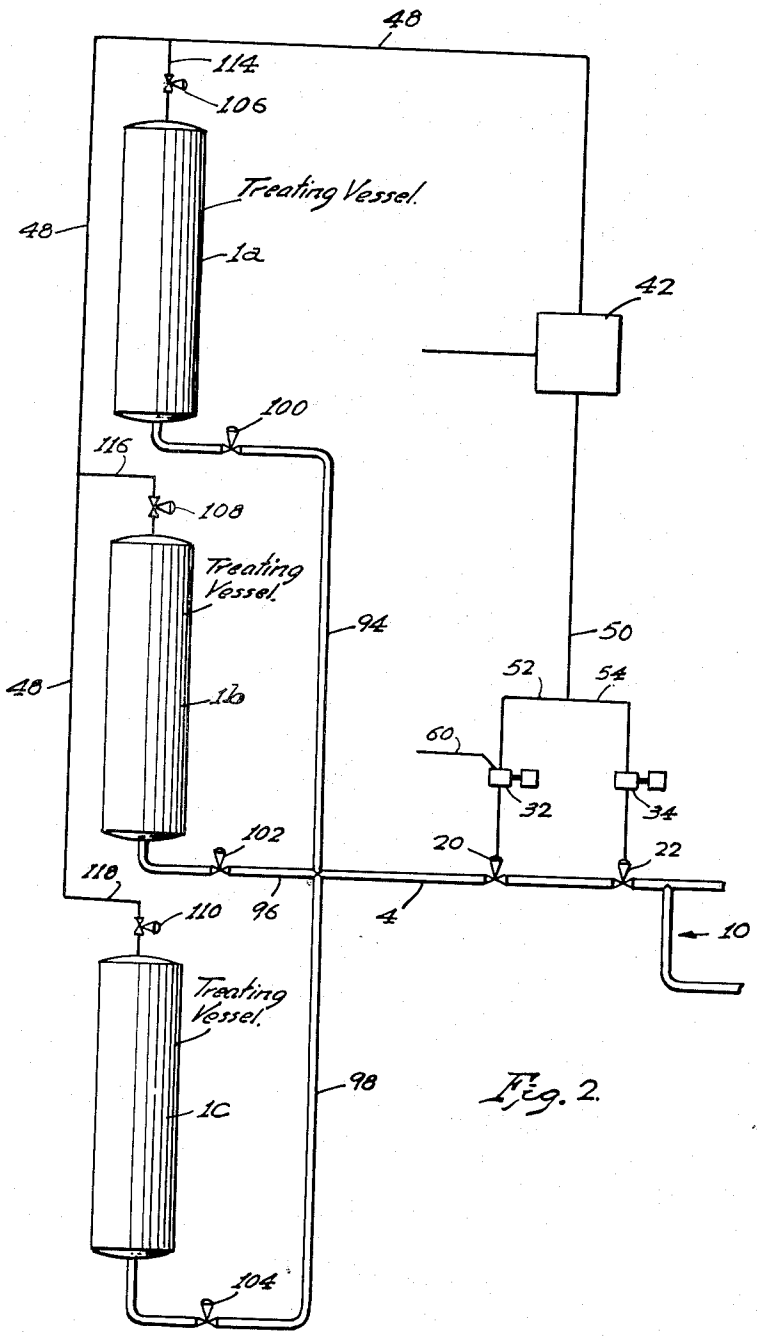


Fig. 2.

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METHOD AND APPARATUS FOR GAS STORAGE

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7 Claims. (Cl. 23—1)

This invention relates to a process involving intermittent treatment of a material in the presence of a gas at elevated pressure, which treatment is alternated with a different treatment in the absence of said gas, and more particularly to the method and apparatus for storage and/or reuse of the gas when its presence in the treating operation is not desired.

Many chemical processes are known which involve the treatment of a material in the presence of a gas at elevated pressure. At some point in these processes it is often desired to terminate the treatment and to perform another operation in the absence of the treating gas. Examples of such processes are hydrogenation processes which are carried out at high pressure in the presence of hydrogen with or without the use of a catalyst, catalytic dehydroaromatization of hydrocarbon oils in the presence of hydrogen, and certain catalytic oxidations of hydrocarbons at elevated pressure, e. g., the oxidation of paraffin hydrocarbons to form aldehydes, acids or alcohols. In the hydrogenation of hydrocarbon oils, for example, it may be desired frequently to terminate the reaction for the purpose of replacing and/or regenerating the catalyst. The same is true of the dehydroaromatization oxidation processes. In certain batch-type processes involving the liquefaction of coal by destructive hydrogenation, it may be desired to terminate the reaction to remove the liquefied charge and replace this with a new charge.

In the past, when such further operation in the absence of the treating gas was desired, it was conventional practice to depressure the treating vessel to the atmosphere, whereupon the desired steps were carried out in the absence of the treating gas.

In hydrogenation and other processes involving the use of a gas under pressure, large volumes of the treating gas may be lost in this manner. In processes involving relatively frequent depressuring, such as the hydrogenation of hydrocarbon oils, the volume of gas lost to the process and the expense entailed thereby may be considerable. Even in processes which make use of less valuable gases, depressuring to a vent is not altogether satisfactory, since considerable time is lost in repressuring to the desired operating pressure by means of a compressor alone.

It is an object of this invention to provide a method and apparatus for use in the type of process described, whereby a treating gas may be stored and subsequently reused. It is a further object to provide an apparatus which will accomplish the above functions automatically and while utilizing a minimum conduit volume. It is a further object to provide an apparatus of the type described which will allow gas flow in opposite directions with the use of a unidirectional pumping means. Still another object is to provide a process and apparatus which will reduce the time required for depressuring and repressuring. An additional object is to provide a process and apparatus which will require a minimum gas storage space. Other objects will appear hereinafter.

These and other objects are accomplished by this invention which is to be used in a process involving intermittent

treating periods carried out in the presence of a gas at elevated pressure and in which the treating periods are alternated with a different operation carried out in the absence of said gas. The improvement of this invention comprises storing the gas, when its presence is not desired, by causing it to flow by pressure differential from a first vessel to a second vessel until approximate pressure equilibrium is reached, then causing substantially the balance of the gas to flow to the second vessel by force. The invention may also include the steps of subsequently causing the gas to flow in the opposite direction by pressure differential until approximate pressure equilibrium is reached, and causing substantially the balance of the gas to flow by force. The invention also includes suitable apparatus and portions thereof for carrying out the various modifications of the process. A further modification involves the employment of a single storage drum for servicing a plurality of treating vessels.

In the accompanying description and drawings certain preferred modifications of the invention are set forth. It is to be understood that they are by way of illustration only and are not to be considered as limiting.

Referring briefly to the drawings, in Fig. 1 there is shown a schematic representation of one suitable apparatus embodying the features of the invention and in Fig. 2 there is shown a plurality of treating vessels which are depressured and repressured with simultaneous storage of gas all in accordance with our invention. Like numbers refer to like parts in Figs. 1 and 2.

In a simple form the invention makes use of a pair of vessels and a conduit connecting these vessels. A valve means is provided in the conduit for regulating the gas flow therethrough. A controlling means responsive to the pressure of one of the vessels is provided for operating the valve means described. A bypass conduit is also provided which bypasses the valve means. The bypass conduit is in operative association with a pumping means. When it is desired to transfer or shift the gas from one vessel to the other, the valve means is caused to open by the controlling means. When gas flow begins, therefore, there is flow through the main conduit, through the valve means, and into the second vessel, with simultaneous flow of a portion of the gas through the bypass, through the pumping means, and into the second vessel. When approximate pressure equilibrium or other predetermined pressure differential is reached, the controlling means, having previously been set according to the desired shifting point, operates to close the valve means and divert all of the gas through the pumping means and into the second vessel.

As will be seen hereinafter more clearly, by providing additional branch conduits and additional valves, alternate paths may be provided through the pumping means whereby gas flow in either direction may be caused, although the pump continues to force gas in the same direction.

A more complex form of the invention involves the use of a plurality of treating vessels in combination with a single storage vessel of a size to contain the gas content of one treating vessel, as illustrated in Fig. 2. By rotating the various treating vessels through the depressuring and repressuring operations, rather than simultaneously performing these steps, a storage vessel of minimum size is required.

Referring now in more detail to Fig. 1 of the drawing, the description of a preferred modification of the invention will be given. Numerals 1 and 2 refer to the two vessels involved in the transfer of gas; vessel 1 is the treating vessel, and vessel 2 acts as the storage drum. A conduit 4 communicates with vessel 1 at one end and with a plurality of conduits at the other. Gas flow may occur from vessel 1 through conduit 4 through conduit 6, conduit 8 and then to drum 2, or from conduit 4 through

conduits 10 and 12, through compressor 14, conduits 16 and 8 into drum 2. An additional path of flow is from conduit 4 through conduits 10 and 18 into drum 2. Flow out of drum 2 may be accomplished through conduit 8 into conduits 6 and 4, out of drum 2 through conduits 18 and 12, through compressor 14, and through conduits 16 and 6 into conduit 4, and out of drum 2 through conduits 18 and 10 into conduit 4.

Numerals 20, 22, 24, 26, 28 and 30 denote conventional spring-loaded, diaphragm motor valves. The indicated structure of the faces and seats of the enumerated valves will show that valves 20, 24 and 26 are direct acting valves while valves 22, 28 and 30 are reverse acting, i. e., air pressure on the diaphragm opens the valves of the former group while air pressure on the diaphragm closes the valves of the latter group. Valve 20 acts as primary means for controlling flow of gas through conduit 4 and valve 30 acts as a secondary means for controlling flow of gas through conduit 4.

Numerals 32, 34, 36, 38 and 40 refer to solenoid actuated switch valves of conventional structure. The solenoids are energized at the control of the main time cycle controller (not shown) which also controls the length of the treating period in vessel 1 as well as other phases of the treating process.

Numeral 42 denotes a pressure controller having a time controlled, cam operated, variable set point. The structure has not been shown in detail, since such instruments are conventional, and since the structure thereof forms no part of the invention. One suitable instrument which will accomplish the functions desired is the Taylor Fulscope Time Schedule Controller manufactured by the Taylor Instrument Company of Rochester, N. Y.

Numerals 44 and 46 refer to pressure controllers having fixed, manually controlled set points. Again, these structures have not been shown in detail, since the particular structure of these instruments forms no part of the invention, and since such instruments are conventional. One suitable type of controller which will accomplish the functions of controllers 44 and 46 is the Fisher Wizard Pilot Controller, type 4100D, manufactured by Fisher Governor Company, Marshalltown, Iowa.

Compressor 14 is of a conventional type and is designed to take suction on one side and produce pressure on the opposite side.

Describing the operation of the illustrated apparatus in detail and assuming that treating vessel 1 is under pressure of, for example 900 p. s. i. g. hydrogen and that storage drum 2 is under low pressure, the solenoid valves 32, 34, 36, 38 and 40 are all deenergized, that is, the center connection is open through the connection opposite the solenoid. The solenoids are deenergized, since no power has been supplied thereto by a change in the main time cycle controller (not shown).

Pressure controller 44 is set to operate valves 28 and 30 by direction of the instrument air output through line 68, through valve 40, through line 70, lines 72, valve 36, lines 74 and 76 to the diaphragm chamber of valve 28 and from line 74, through line 77 to the diaphragm chamber of valve 30, but since the pressure in drum 2 is below the setting of pressure controller 44, there is no instrument air output and these valves are open. Valves 24 and 26 are held open by the auxiliary air supplied through line 88, through valve 38, and lines 84, 86 and 87. Pressure controller 46 is, in effect, out of service, since its output is blocked off in solenoid valve 40.

Valve 20 is held open by the auxiliary air supplied through line 60, through valve 32, through line 56, to the diaphragm chamber of the valve. Pressure controller 42, which is responsive to the pressure in vessel 1 through line 48, controls valve 22 by its instrument air output which passes through lines 50, 54, valve 34, line 58 and to the diaphragm chamber of valve 22.

As the cam in pressure controller 42 sets the index pointer below the actual pressure in vessel 1, valve 22 opens as required to release pressure from vessel 1 into drum 2. Flow at this point is from vessel 1 through conduit 4, through conduits 6 and 8 into drum 2; through conduits 4, 10, and 18 into drum 2; through conduits 4, 10 and 12, through compressor 14 into conduits 16 and 8, and into drum 2. This depressuring continues at the set rate controlled by the cam movement of pressure controller 42, i. e., the degree of difference between the pressure of vessel 1 and the set point of pressure controller 42 (which governs the degree of opening for valve 22) is maintained as desired by previous shaping of the cam. Depressuring is advantageously controlled to avoid undue carry-over of extraneous material, e. g., catalyst, to storage vessel 2.

When the pressure in the storage drum 2 reaches approximate equilibrium (about 450 p. s. i. g. in the present instance) with that in vessel 1, pressure controller 44, whose set point has been adjusted to correspond with this pressure, has an output of instrument air through line 68, valve 40, lines 70 and 72, valve 36, and lines 74, 76 and 77, by means of which valves 28 and 30 are closed. Only one path of flow for the gas remains, namely, from vessel 1 through conduits 4, 10 and 12, through compressor 14 into conduits 16 and 8 and thence into drum 2.

The compressor 14, which runs continuously, pumps the gas into the storage drum. Pressure controller 46 may be set at, for example, in this instance, 550 p. s. i. g. When the pressure in drum 2 reaches this figure, the instrument air output builds pressure, but has no effect, since the output is blocked off in valve 40.

Compressor 14 continues to take suction on vessel 1 until this vessel has been substantially evacuated. Since it is impractical to completely evacuate a vessel of gas by means of a compressor, the vessel is not completely evacuated, and the remaining small quantity of gas may be vented to the atmosphere through an auxiliary line (not shown).

When vessel 1 reaches the predetermined degree of evacuation, e. g., 1 atmosphere pressure, valve 22 closes, since the cam of pressure controller 42 now maintains the set point above the pressure of vessel 1. This blocks off the treating vessel from the storage system. In addition, another valve (not shown), controlled by the main time controller (not shown), may be provided between valve 20 and vessel 1, in order to insure blocking off of the storage system during steps performed in vessel 1 in the absence of the gas.

After vessel 1 has been depressured, and when vessel 1 or some other vessel is ready for repressuring, the main time controller (not shown) energizes the solenoids of valves 32, 34, 36, 38 and 40 causing these valves to switch. Pressure controller 44 is now out of service, since the instrument air output is blocked off in valve 44. Pressure controller 46 is in service, since the pressure in drum 2 exceeds the controller's set point (550 p. s. i. g.), and this controller holds valves 24 and 26 open by direction of the instrument air output through line 80, valve 40, lines 70 and 82, valve 38, lines 84, 86 and 87 to the diaphragm chambers of the valves indicated. Valves 28 and 30 are open due to venting of the diaphragm pressure through lines 77, 76 and 74 through vent 78. Valve 22 is held open by venting the diaphragm through line 58, through vent 62. Pressure controller 42 is now controlling valve 20.

At this point, it will be seen that the possible paths of flow are from storage drum 2 through conduits 8, 6 and 4 into vessel 1, from drum 2 through conduits 18, 10 and 4 into vessel 1, and from drum 2 through conduits 18 and 12 through compressor 14 through conduit 16, 6 and 4 and into vessel 1.

As the cam in pressure controller 42 sets the index pointer above the pressure in vessel 1, there is an instrument air output which is directed through lines 50 and 52 through valve 32 through line 56 and into the diaphragm

of valve 20, causing it to open and admit gas at a controlled rate into vessel 1. When the pressure in the storage drum 2 falls below the set point of pressure controller 46 (550 p. s. i. g.), instrument air output ceases, and valves 24 and 26 close. The closing of valves 24 and 26 leaves open only one path of flow, namely that from storage drum 2 through conduits 18 and 12 through compressor 14 through conduits 16, 6 and 4 and into vessel 1. Compressor 14 continues to pump gas from drum 2 into vessel 1 until repressuring is completed. Again, the storage drum 2 need not be completely evacuated for the reason given in connection with the evacuation of vessel 1.

It may often be desirable to provide a bypass (not shown) in the main conduit between vessel 1 and vessel 2 containing a guard filter or liquid trap to prevent carryover of extraneous material to storage vessel 2. During the return flow this filter or trap may be bypassed. Where a catalytic treating process, e. g., a catalytic hydrogenation, is being carried out in treating vessel 1, a guard filter drum is desirable to prevent carryover of catalyst. In a reaction such as the batch liquefaction of coal it may be desirable to supply a liquid trap to prevent carryover of liquefied material into storage drum 2. The filter or trap may be advantageously placed as close to the treating vessel as is convenient and may be located in either the main conduit or the bypass.

Another advantageous modification of the invention is in combination with a plurality of treating vessel. In this modification the treating periods in the various treating vessels may be begun in progressive or consecutive fashion. Consequently, the treating vessels become ready for depressuring in similar consecutive fashion. The gas contained in the first treating vessel to become ready for depressuring is conveyed to the storage drum in the manner described above. When the same or some other treating vessel is ready for repressuring, the gas contained in the storage vessel is reconveyed thereto in the manner set forth. The treating vessels are then consecutively rotated through the depressuring and repressuring operations as they become ready. The storage vessel employed in this modification is of a size sufficient to contain a single charge of gas, i. e., the gas content of one treating vessel. Accordingly, a single storage vessel of minimum size is made to serve for a large number of treating vessels.

This mode of operation will be readily apparent from a consideration of Fig. 2. Referring to Fig. 2, numerals 1–*a*, 1–*b*, and 1–*c* designate a plurality of treating vessels which are connected to conduit 4 by conduits 94, 96 and 98 respectively. Conduit 94 is provided with a time cycle controlled valve 100; conduit 96 is provided with a time cycle controlled valve 102 and conduit 98 is provided with a time cycle controlled valve 104. Treating vessels 1–*a*, 1–*b*, and 1–*c* are connected to conduit 48 by means of conduits 114, 116 and 118 respectively. Conduit 114 is provided with time cycle controlled valve 106; conduit 116 is provided with time cycle controlled valve 108 and conduit 118 is provided with time cycle controlled valve 110.

The operation of the apparatus illustrated in Fig. 2 is identical to the operation of the apparatus described in connection with Fig. 1 except that treating vessels 1–*a*, 1–*b* and 1–*c* are connected in sequence to conduits 4 and 48. In other words, one of these treating vessels is connected to these conduits through the time cycle controlled valves, while the other two treating vessels are isolated therefrom by the time cycle controlled valves with which they are provided. Thus, when treating vessel 1–*a* is connected to conduits 48 and 4, time cycle controlled valves 106 and 100 would be open, whereas, time cycle controlled valves 108, 102, 110 and 104 would be closed. When the operations in treating vessel 1–*a* have been completed, the time cycle controlled would close valves 106 and 100 and thus isolate treating vessel 1–*a* from the gas storage system. The time cycle controller at the same time would open vaves 108 and 102 thereby connecting

vessel 1–*b* to the gas storage system through conduits 4 and 48. Upon completion of this operation, treating vessel 1–*b* would be isolated by closing valves 108 and 102. Treating vessel 1–*c* would then go through the same operations as described in connection with vessels 1–*a* and 1–*b*.

The particular conditions involved in the treating process which take place in vessel 1 of Fig. 1 and vessels 1–*a*, 1–*b* and 1–*c* of Fig. 2 and the necessary lines, valves, etc., for the particular processing desired have not been described in detail, since they form no part of the invention.

Although a particularly preferred modification of the invention has been illustrated in the drawing, various modifications will be readily apparent to those skilled in the art. Accordingly, we do not intend to be limited to the particular apparatus shown.

One advantage of the invention is that it provides a process and apparatus for storage and/or reuse of a gas at elevated pressure. Another advantage is that these functions have been accomplished with a minimum conduit volume and while utilizing a unidirectional pump. A still further advantage is that the operations may be performed automatically, Another advantage is that the storage of the gas content of several vessels may be effected with the utilization of a storage vessel of minimum size.

What we claim is:

1. In a process involving a plurality of treating vessels in which intermittent treating steps are carried out in the presence of a gas at elevated pressure, said treating steps being alternated with a different operation carried out in the absence of said gas, the improvement which comprises staggering the times for terminating the treating steps, whereby the treating vessels become ready for depressuring in consecutive fashion, storing the gas contained in the first treating vessel, when that vessel is ready for depressuring, by causing the gas to flow by pressure differential from the treating vessel to a storage vessel sized to contain the gas content of one treating vessel, continuing to cause flow in the manner described until approximate pressure euqilibrium is reached, then causing substantially the balance of the gas to flow to the storage vessel by force, subsequently causing the gas to flow in the opposite direction from the storage vessel to a treating vessel by pressure differential until approximate pressure equilibrium is reached, then causing substantially the balance of the gas to flow by force, and repeating the depressuring and repressuring operations with each treating vessel as it becomes ready therefor, whereby minimum storage space is required.

2. In a process involving a plurality of treating vessels in which intermittent treating steps are carried out in the presence of a gas at elevated pressure, said treating steps being alternated with a different operation carried out in the absence of said gas, the improvement which comprises staggering the times for terminating the treating steps, whereby the treating vessels become ready for depressuring in consecutive fashion, storing the gas contained in the first treating vessel, when that vessel is ready for depressuring, by causing the gas to flow simultaneously by pressure differential and by force through two paths from the treating vessel to a storage vessel sized to contain the gas content of one treating vessel, continuing to cause flow in the manner described until approximate pressure equilibrium is reached, then causing substantially the balance of the gas to flow to the storage vessel by force alone, subsequently causing the gas to flow in the opposite direction from the storage vessel to a treating vessel simultaneously by pressure differential and by force until approximate pressure equilibrium is reached, then causing substantially the balance of the gas to flow by force alone, and repeating the depressuring and repressuring operations with each treating vessel as it becomes ready therefor, whereby minimum storage space is required.

3. A system for periodic storage and reuse of a gas

comprising in combination a vessel in which the gas is to be used, a gas storage vessel, a main conduit connecting the vessels, primary valve means regulating gas flow through said main conduit, secondary valve means adapted to regulate gas flow through said main conduit, a bypass conduit for bypassing said secondary valve means, said bypass conduit connecting the storage vessel with said main conduit, a cross conduit connecting said main conduit, between the secondary valve means and the storage vessel, with said bypass conduit, unidirectional pumping means positioned in the cross conduit, valve means positioned in said bypass conduit adapted to divert gas flow through said cross conduit, time controlled means for actuating the valve in said bypass conduit at predetermined times, means responsive to the pressure of the storage vessel for controlling the valve means in said bypass, valve means positioned in said main conduit between the cross conduit and the storage vessel, said last mentioned valve means being adapted to close off said storage vessel from said pumping conduit, and time controlled means for actuating said last mentioned valve at predetermined times.

4. A system for periodic storage and reuse of a gas comprising in combination a treating vessel, a storage vessel, a main gas conduit communicating with the treating vessel and terminating in at least two branch conduits which communicate with the storage vessels, a cross conduit connecting two of said branch conduits, unidirectional pumping means in association with said cross conduit, primary valve means in association with said main conduit, a first controlling means responsive to the pressure of the treating vessel for operating said primary valve means, said first controlling means having a time controlled set point and being adapted to open the primary valve means when gas flow is desired, secondary valve means positioned in said branch conduits adapted to close all paths of flow except that from the treating vessel through the pumping means to the storage vessel, tertiary valve means positioned in said branch conduits and adapted to close all paths of flow except that from the storage vessel through the pumping means to the treating vessel, a second controlling means responsive to the pressure of the treating vessel for operating one of the secondary and tertiary valve means, auxiliary means for operating the other of said secondary and tertiary valve means, time controlled directing means for directing the control of the second controlling means to one, and for directing the control of the auxiliary means to the other of said secondary and tertiary valve means, all of said controlling and said auxiliary means being adapted to open all valve means when gas flow is initially desired, said second controlling means being adapted to operate when approximate equilibrium pressure between the vessels is reached, said time controlled directing means being adapted to select in predetermined fashion the path of gas flow.

5. Apparatus for gas shifting comprising in combination a vessel, a pair of conduits leading out of the vessel, a cross conduit connecting the pair of conduits, a first pair of valves, one of which is positioned in one of the pair of conduits and the other of which is positioned in the other of the pair of conduits, one of said valves being positioned nearer the storage vessel than the cross conduit and the other being positioned further from the storage vessel than the cross conduit, a second pair of valves one of which pair is positioned in one of the conduits so that it is nearer the storage vessel than the cross conduit and the other of which pair is positioned further from the storage vessel than the cross conduit and being in that conduit in which that valve, of the first pair of valves is positioned nearer the storage vessel, controlling means responsive to the pressure of the vessel for operating one of said pairs of valves, auxiliary means for operating the other of said pairs of valves, and time controlled means for directing which pair of valves is to be operated by the controlling means.

6. A gas handling apparatus comprising in combination a plurality of treating vessels, a single storage vessel sized to contain the gas content of a single treating vessel, a main conduit connecting the storage vessel with each of the treating vessels, primary valve means regulating gas flow through said main conduit, secondary valve means adapted to regulate gas flow through said main conduit, a bypass conduit for bypassing said secondary valve means, said bypass conduit connecting the storage vessel with said main conduit, a cross conduit connecting said main conduit between the secondary valve means and the storage vessel with said bypassing conduit, unidirectional pumping means positioned in the cross conduit, valve means positioned in said bypassing conduit, adapted to divert gas flow through said pumping conduit, time controlled means for actuating the valve means at predetermined times and positioned in the bypassing conduit, means responsive to the pressure of the storage vessel for controlling the valve means in said bypass conduit, valve means positioned in said main conduit between the cross conduit and the storage vessel, said last mentioned valve means being adapted to close off said storage vessel from said pumping conduit, time controlled means for actuating the last mentioned valve means at predetermined times, and means for successively depressuring and repressuring the vessels.

7. The process for removing a gas from a treating vessel filled with gas under pressure and for refilling the treating vessel with the same gas without substantial loss of said gas which comprises in combination expanding the gas in the treating vessel through three passageways into a storage vessel until the pressure in both vessels is about equal, closing two of the passageways and pumping gas via the unclosed third passageway until the treating vessel is at about atmospheric pressure, refilling the treating vessel by expanding the gas from the storage vessel through three passageways into the treating vessel until the pressure in both vessels is about equal, closing two of the passageways and pumping gas via a third passageway until the treating vessel is at about its original pressure, the direction of flow through a portion of both of said third passageways being the same during the emptying and refilling operations whereby the same unidirectional gas pump can be utilized for both the emptying and refilling operations.

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