Feb. 21, 1956 P. K. RICE 2,735,278

COLD ACCUMULATOR

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Fig. 1.

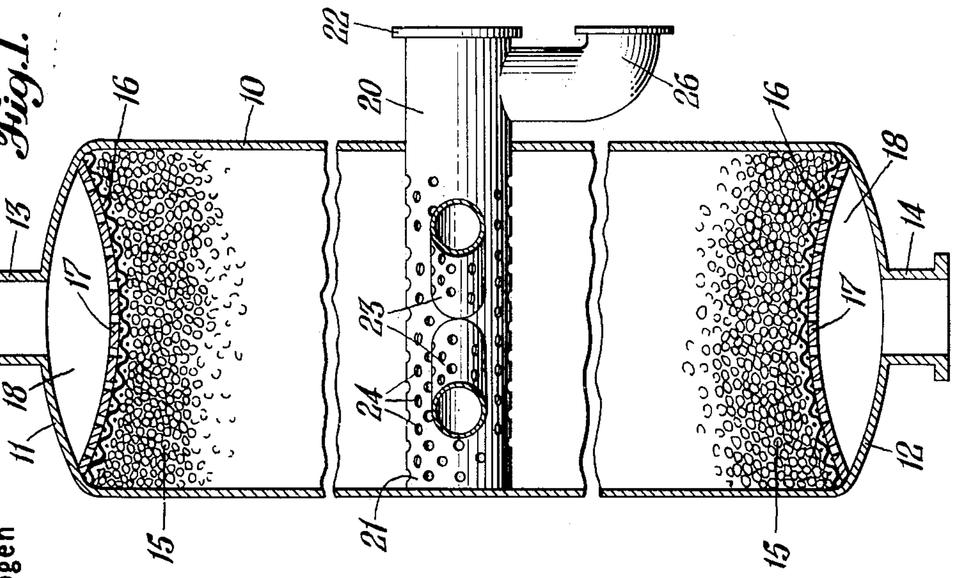
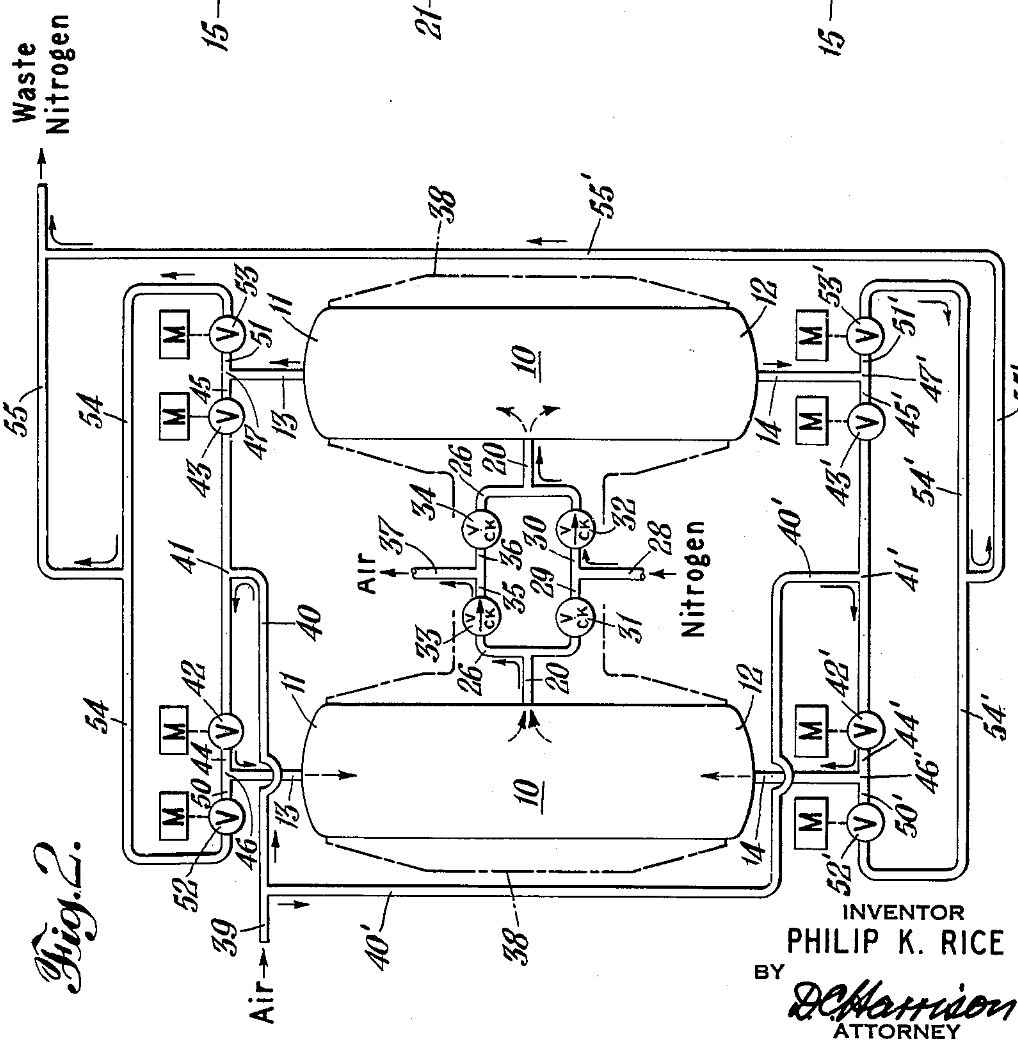


Fig. 2.



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COLD ACCUMULATOR

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This invention relates to cold accumulator heat exchange devices for effecting heat exchange between an impurity containing gas or gas mixture to be cooled and an impurity-free gas to be warmed.

Cold accumulators or cold regenerators are used for cooling gas mixtures such as air which is to be separated at low temperature into its components such as oxygen and nitrogen products and wherein the gaseous separation products are used to cool the accumulators. Such devices are found especially useful in systems wherein the gas mixture or air is supplied at pressures only slightly above the pressure at which the mixture, after it is cooled by passage through the cold accumulator to a temperature close to its condensation temperature at the supply pressure, can be liquefied by heat exchange with a boiling liquid comprising the higher boiling product when boiling at a pressure close to atmospheric pressure. The cold accumulators commonly used are pressure resistant chambers filled with a heat storing filler mass. For example, a widely used filler mass consists of spirals of thin, corrugated metal as described in U. S. Patent Re. 19,140 of M. Frankl. Heat storing filler masses consisting of pellets in graded sizes have also been used. Two such chambers containing heat storing material form a working set, the warm and cold ends of the chambers being connected by piping controlled by reversing valves so arranged that the compressed gas mixture to be used may flow through one chamber of the set from the warm to the cold end while the cold impurity-free product gas at low pressure flows through the second chamber of the set from the cold to the warm end. The reversing cycle is such that the flow in one direction continues for a short time, from 2 to 5 minutes, for example, after which the flows are switched so that the outgoing product cools the filler mass of the one chamber and the incoming mixture is cooled by the filler mass of the second chamber.

A particular advantage of cold accumulator heat exchange for cooling an impurity-containing gas is that condensable impurities, such as water vapor and carbon dioxide, are deposited on the extended surface of the filler mass and so removed from the gas mixture. Under proper conditions of operation such as those set forth by Mr. Frankl in U. S. Patent No. 1,970,299, the outgoing product gas has a larger specific volume than the incoming gas mixture so that the condensed materials are re-evaporated and swept out of the heat storage mass without loss of refrigeration. When the accumulators are switched it is necessary to blow-down or release the higher pressure gas mixture from the chamber containing it so that the pressure therein is reduced to the pressure of the outgoing cold product gas in order that such cold product may flow therethrough. This blow-down represents a loss of compressed gas, or at least a loss of the work of compressing the blow-down gas. It is therefore desirable to keep the volume of space in the chambers which is unoccupied by the filler mass and the volume of the piping on the chamber side of the control valves as small as is practical.

A certain amount of blow-down loss can be saved by interposing a step of pressure equalization between chambers after the stopping of one period of gas flow and before the beginning of a reversed period of gas flow. As described in the Patent 2,107,335, to R. Linde et al., to effect such equalization step requires an extra valve cross-connected between the warm ends of the cold accumulator chambers and this adds to the piping space to be blown down. The latter patent also illustrates the presently preferred use of four motor-operated stop valves which are operated in response to a timing device to act as reversing valves at the warm ends of the accumulators. It also shows a presently preferred use of four check valves at the cold ends which check valves are horizontally positioned clapper type valves that impose relatively small flow resistance in the open flow direction.

The cold accumulator type of heat exchange devices are particularly advantageous for relatively large flow volumes. Up to a certain flow volume it is found that a set comprising two cold accumulators piped for alternate flow substantially as illustrated in the aforesaid Patent 2,107,335, but not necessarily including the cross connection **16** and valves **21** and **26**, provides satisfactory results. When it is necessary to handle flow volumes up to double that for which the larger sizes of cold accumulators have been used, certain difficulties are encountered. Since the length of flow path through the filler mass is limited by the maximum permissible pressure drop of the larger volume cold outgoing gas, it is necessary to gain the increased flow capacity by increasing the cross section of the chambers. However, it is found impractical to increase the diameter of the chambers because the filler mass bed becomes wider than it is deep and the maintenance of equal distribution of flow through the mass involves difficulties, especially with the resublimation of deposed material from the mass by the outgoing product. A further important difficulty results because the greater diameter produces chambers difficult to ship, and the end heads become greater than the available standard manufactured tank heads. Special end heads are very expensive.

A commonly proposed solution for handling larger flows is to use four or more cold accumulator chambers per set instead of two. It is found, however, that this results in substantially increased complications in the piping to the warm and cold ends. With four regenerators per set it is common to use two motor operated warm end valves for each regenerator, resulting in a total of eight warm end valves. If cold end check valves are used in branches to each pair of parallel operating chambers only four cold end check valves would be needed. However, the gas space in the T's and connections add to the volume of the regenerator which has to be blown down upon reversal, and, in order to keep this blow-down volume as low as is practical, it is preferred to use two check valves on the cold end of each accumulator chamber which results in eight valves also at the cold end.

When four cold accumulator chambers constitute a set there are eight end heads and each end head must be constructed to provide a space for the equal distribution of gas to the filler mass. Hence there are eight head spaces, unoccupied by the filler mass, which contribute to the volume of space that must be blown down. Also, when four cold accumulator chambers are used for a set there are four cold ends which have end surfaces that must be protected from the leakage of heat thereto from ambient atmosphere.

Principal objects of the present invention are to provide a cold accumulator construction that has double the flow capacity of a set of two cold accumulators of equal diameter, and which also has less volume to be blown down than a set of four cold accumulators of equal flow capacity, thereby providing lower blow-down losses; which requires half the number of cold end valves that is used for a set of four cold accumulators; in which the cold end piping is considerably simplified and is positioned so that the valves are more accessible for servicing; which eliminates the use of cold end chamber heads and the insulation thereon so as not only to reduce the cost of such heads and insulation, but also to reduce the cold end chamber wall area through which refrigeration may be lost to ambient atmosphere; which permits the convenient use of horizontally positioned clapper check valves for low pressure drop and with relatively small piping volume between such valves and the cold accumulator chambers; in which the cold end valves need not be deeply embedded in an inaccessible mass of insulation but are so accessible for servicing that, if desired, motor operated cold end valves can be employed to further reduce pressure losses; which eliminates the probability of unbalanced flows of outgoing cold gas due to unequal pressure drops through valves and connections operating in parallel; which permits operation at one-half full flow capacity or at full flow capacity with substantially equal efficiency; and which provides the above named advantages with operating heat exchange efficiency of the same order as that of conventional two unit cold accumulators employing the same type of heat storage mass. These and other objects of the invention will become apparent from the following description in connection with the accompanying drawing in which:

Fig. 1 is a longitudinal cross-sectional view of a cold accumulator chamber according to the present invention; and Fig. 2 is a flow diagram showing two of the cold accumulators of Fig. 1 connected to operate as a set.

Referring now to Fig. 1 the cold accumulator according to the present invention comprises a chamber shell **10** having a diameter similar to the customary cold accumulator designed for one-half the flow capacity of the cold accumulator shown in Fig. 1. The end heads **11** and **12** which close ends of the chamber are both warm ends. It is thus seen that the cold accumulator has no cold end but has two warm ends. Gas pipe connections **13** and **14** are secured centrally of each warm end head respectively. The accumulator chamber **10** may be filled with any suitable heat storage mass. The heat storage mass shown, and preferred because it is less expensive, consists of pellets **15**. The pellets are retained in the chamber at each end by suitable means such as screen **16** supported upon perforated and dished heads **17**, the heads **17** being inwardly dished to provide a gas space **18** at each end of the chamber **10** for equal distribution of gas flow to the filler material **15**. Obviously any suitable means for retaining the pellet filler material in place may be used.

The gas to be cooled and the gas which has been warmed up enter and leave through the connections **13** and **14**. Means is provided at the mid-point of the chamber **10** for the exit of cooled gas mixture and the entry of cold outgoing product. A convenient form of such means may comprise a pipe **20** which passes diametrically across the shell **10** and has one end **21** secured to the inner wall of the shell **10** and the other end passing gas-tightly through the opposite side of the shell **10** and ending in a connecting flange **22**. There may also be angular braces in the form of tubes **23** secured between the pipe **20** and the inner wall of the shell **10**. The portion of the pipe **20** within the shell **10** is provided with perforations **24** to effect distribution of the gas into the filler mass and to this end the braces **23** may also be perforated and communicate with the pipe **20**. The perforations **24** may be covered with a suitable screen or they may be smaller than the pellets and sufficiently numerous to provide the desired flow area. The portion of the pipe **20** between the shell **10** and the flange **22** may have a branch connection **26** secured thereto.

To form an operating set, two of the regenerator chambers **10** may be connected as shown in Fig. 2. The cold gas to be warmed, for example, effluent nitrogen from an air separation apparatus, may be conducted to the regenerator set through a pipe **28** having branches **29** and **30** connecting with the inlet openings of check valves **31** and **32**. The outlet sides of these check valves are preferably directly coupled to the open ends **22** of the pipes **20**. The check valves **31** and **32** are oriented so that they permit gas flow only in the direction from the pipe **28** toward either of the chambers **10**. Oppositely oriented check valves **33** and **34** have their inlets coupled respectively to the branches **26** of the left and right hand chambers **10**, and the outlets of the check valves **33** and **34** are coupled to branches **35** and **36** of a cold air conduit **37**. It will be seen that each of the check valves may be mounted very conveniently in the desired horizontal position and located at the sides of the chambers **10** where they are readily accessible. It should also be observed that the thickest heat insulation, indicated by the dotted outline **38**, is located about the middle portions of the regenerator chambers **10**. The cold pipes **28** and **37** as well as the piping including the pipe **20** outside of the shells **10** are also covered with heat insulation effective to prevent leakage of heat to the gases flowing through such passages. The end heads **11** and **12** ordinarily will need no heat insulation and the piping at the warm ends of the regenerator sets also does not require to be insulated.

Since the piping and valves at both warm ends are substantially the same, that for the upper warm end only will be described. The gas mixture or air to be cooled is supplied from a source **39** through a conduit **40** which branches at **41** to motor operated valves **42** and **43**. The other openings of the motor operated valves **42** and **43** are coupled to branches **44** and **45** of T connections **46** and **47** that have branches coupled to the outlets **13** at the top of each chamber **10**. The remaining branches **50** and **51** of the T's **46** and **47** respectively are coupled to motor operated valves **52** and **53** and the outlets of the valves **52** and **53** in turn connect to branches **54** of a conduit **55** that conducts the warmed outgoing gas to a desired point. Each of the valves **42** and **43**, **52** and **53**, is provided with a valve operating means which may be an air motor or electric solenoid or other suitable device. Such devices are indicated diagrammatically at M. The piping at the lower warm ends of the chambers **10** has its parts corresponding to those at the upper end indicated by similar reference numbers primed ('), the branches of the T connections **46'** and **47'** being connected to the lower nozzles **14**.

The gas flow during one period of operation is as follows: Air to be cooled comes in through conduits **40**, **40'** and flows from branch points **41** and **41'** through valves **42** and **42'** which are held simultaneously open by their respective motor devices. The valves **43** and **43'** are closed during such period. The air flows through T's **46** and **46'** and through left hand connections **13** and **14** and the filler material **15** from the warm ends toward the center of the left hand chamber **10**. On its passage through the heat storage material the air gives up its heat to the heat storing material and becomes chilled to a very low temperature by the time it reaches the pipe **20**. Such air also first deposits the water vapor in the form of frost on the heat storage material and then deposits the carbon dioxide. The cold clean air flows out through the left hand connection **20**, check valve **33** and into the cold air conduit **37** which conducts it to the air separation apparatus. Simultaneously, a product of air separation, nitrogen, for example, flows through conduit **28**, check valve **32** and the right hand pipe **20** into the center part of the right hand chamber **10**. Such nitrogen flows outwardly toward connections **13** and **14** and during its passage through the heat storage material **15**, absorbs the stored heat therefrom and at the same time effects sublimation and evaporation of the deposited carbon dioxide and water vapor. The impurity laden warm product nitrogen then flows through the trees 47 and 47′ and branches 51 and 51′ and the valves 53 and 53′ which are held open by their respective motor devices. The waste nitrogen is conducted away through the conduits 55 and 55′.

After the desired period, for example, 2 to 5 minutes, the valve timing device effects switching of the valves. The valves 42 and 42′ are closed while the valves 52 and 52′ are gradually opened to blow down the pressure from the chamber 10 into the waste nitrogen conduits 55 and 55′. Valves 52 and 52′ remain open while valves 43 and 43′ are opened. The air flows from conduits 40 and 40′ through the valves 43 and 43′ and inward through the right connections 13 and 14 toward the center of chamber 10. Such air will rapidly overcome the nitrogen pressure and effect the closing of the check valve 32 and opening of check valve 34 so that the cold air flows out through the right hand pipe 20 through check valve 34 to the cold air conduit 37. When the pressure in the left hand chamber 10 has been blown down and reduced to a pressure slightly below that of the nitrogen in conduit 28 the check valve 31 will be opened by nitrogen which will flow therethrough and into the left chamber through the left pipe 20. The air pressure in pipe 37 will have previously closed the check valve 33 when the left chamber 10 was blown down.

If the nitrogen product is desired in a purer state, or if the regenerator set is to be operated for warming an oxygen product, which it is desired should not be diluted with the blown down air, it will be necessary to provide blow-down valves for exhausting such air to the atmosphere. Such blow-down valves are not illustrated in the interests of clearness of the drawing. If used they could be connected into a portion of the T connections 46 and 47, 46′ and 47′, or any suitable location between the warm ends of the chambers 10 and the warm end reversing valves.

If it should be desired to operate the regenerator set illustrated in Fig. 2 at one-half the full flow volume, it is merely necessary to keep all the valves at one or the other warm ends closed all the time. In such a case and if it should be desired to operate only the upper halves of the chambers 10, the valves 42′, 43′, 52′ and 53′ would remain closed, and the air would flow in through conduit 40, valve 42 and connection 13 to the upper half only of the left chamber through the connection 20 and out through the pipe 37, while the nitrogen would flow from conduit 28 through check valve 32, connection 20 upwardly through the upper half of the right chamber 10 and connection 13, through valve 53 to the conduit 55. Similarly, and with equal efficiency, the lower halves only of the chambers 10 could be employed, in which case the valves 42, 43, 52 and 53 would remain closed while the valves 42′, 43′, 52′ and 53′ would be operated cyclically.

If it should be necessary to effect thawing of the cold accumulators according to the present invention, this can be very safely effected simply by passing a dry warm gas through the chamber 10 in one warm end and out the other warm end until the heat storage mass and pipe 20 have been heated sufficiently to clear out all moisture deposits. In this way all danger of getting any water due to the melting of frost deposits into the cold check valves is avoided.

It will be seen, as compared to an equal capacity of a four chamber cold accumulator set, that the cold end heads have been completely eliminated and with them the spaces corresponding to spaces 18 for distribution of gas. Space equivalent to at least two such spaces has been eliminated, thereby eliminating a substantial portion of the space which holds gas under pressure prior to blow-down. Instead of four cold end T connections there are now only two connections 26 equivalent to T connections and therefore the space in such connections between the chambers 10 and the check valves 31, 33, or 32, 34 is at least halved. The cold accumulator construction according to the invention also permits the efficient use of only four instead of eight cold check valves and these are very conveniently mounted in a horizontal position so that they operate with low pressure drop and are less subject to sticking and unequal resistance to opening. The elimination of cold end heads eliminates the need for thick insulation thereon and also eliminates a substantial portion of the heat that tends to flow from the ambient atmosphere through the gas through such cold end heads. The need for one outgoing nitrogen check valve in operation at any time eliminates any possibility of unbalanced nitrogen flow which readily occurs where the outflowing nitrogen must be divided into two equal parallel paths of flow through two check valves.

More space can be saved by having the pipe 20 extend through opposite walls of the chamber 10, omitting the connection 26 and providing each end of the pipe 20 with check valve connecting flanges closer to the shell 10 than the flange 22. An inwardly opening check valve would be connected to one end of pipe 20 for admitting cold nitrogen and an outwardly opening check valve would be connected to the other end of the pipe 20 for withdrawal of cooled air.

It will be understood that various changes may be made in the constructions set forth above without departing from the spirit and scope of the invention.

What is claimed is:

1. A cold accumulator having a chamber defined by side walls closed by end heads; warm gas conduit means associated with each of said end heads; cold gas conduit means associated with said chamber intermediately of said end heads and adapted for separate withdrawal from and supply to said chamber of cold gas, said cold gas conduit means being in simultaneous gas flow communication with both of said warm gas conduit means at said end heads and comprising a gas distributor constructed to distribute the flow of gas at the central portion of said chamber in communication with conduit means extending gas-tightly through said side walls of said chamber; and heat storage filler mass disposed within said chamber substantially equally between each end head and said cold gas conduit means.

2. A cold accumulator in accordance with claim 1, in which said chamber has cylindrical walls and said end heads are outwardly dished; and which includes retainers for the heat storage material comprising perforated inwardly dished plates secured internally of said end heads to provide a gas distributing space internally of each end head.

3. A cold accumulator in accordance with claim 1, including a jacket of heat insulation, said heat insulation jacket covering only the external wall portion between said end heads.

4. Cold accumulator heat exchange apparatus comprising a set of chambers, each such chamber having two end heads with warm gas connections, heat storage mass within said chambers, and pipe connections intermediate said end heads adapted for alternately supplying and withdrawing cold gas; reversing valves and conduits connecting to the warm gas connections at opposite ends of said chambers constructed and arranged to simultaneously feed warm gas to be cooled to both warm ends of one of said chambers while withdrawing a warmed gas from both warm ends of the other of said chambers and for cyclically reversing such flows; valves controlling the supply of cold gas to be heated to one or the other of said intermediate pipe connections; and valves for controlling the withdrawal of cooled gas from the opposite one or other of said intermediate pipe connections.

5. In the operation of a cold accumulating heat exchanger having a chamber defined by side walls closed by end heads, first gas conduit means associated with each of said end heads, second gas conduit means in said chamber positioned intermediately of said end heads,

and heat storage filler mass disposed within said chamber substantially equally between each end head and said second gas conduit means, said second gas conduit means being in simultaneous gas flow communication with both of said first gas conduit means at said end heads through the filler mass, the steps comprising concurrently introducing a warm gas into both of said first gas conduit means, and withdrawing cooled gas from said second gas conduit means, thereby operating said heat exchanger so that both ends are warm and so that there is no cold end exposed through which heat is absorbed from the atmosphere.

6. In the operation of a heat exchanger having a chamber defined by side walls closed by end heads, first gas conduit means associated with each of said end heads, second gas conduit means in said chamber positioned intermediately of said end heads and heat storage filler mass disposed within said chamber substantially equally between each end head and said second gas conduit means, said second gas conduit means being in simultaneous gas flow communication with both of said first gas conduit means at said end heads through the filler mass, the steps comprising introducing a cold gas into said second gas conduit means, and withdrawing warmed gas concurrently from both of said first gas conduit means, thereby operating said heat exchanger so that both ends are warm and so that there is no cold end exposed through which heat is absorbed from the atmosphere.

7. In the operation of cold accumulator heat exchange apparatus having first and second chambers defined by side walls and closed by end heads, each of said chambers having first gas conduit means associated with each of said end heads, second gas conduit means therein positioned intermediately of said end heads, and heat storage filler mass disposed therein substantially equally between each end head and said second gas conduit means, said second gas conduit means being in simultaneous gas flow communication with both of said first gas conduit means at said end heads, the steps comprising concurrently introducing a warm gas into said first gas conduit means of said first chamber and a cold gas into said second gas conduit means of said second chamber, concurrently withdrawing cooled gas from said second gas conduit means of said first chamber and warmed gas from each of said first gas conduit means of said second chamber, and periodically reversing the flows so that during a second portion of the reversing cycle, a warm gas is introduced into each of said first gas conduit means of said second chamber, cooled gas is withdrawn from the second gas conduit means of said second chamber, a cold gas is introduced into the second gas conduit means of said first chamber, and warmed gas is withdrawn from each of said first gas conduit means of said first chamber.

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