June 4, 1963 R. BECKER 3,091,941

PROCESS AND APPARATUS FOR REFRIGERATION BY WORK-PRODUCING EXPANSION

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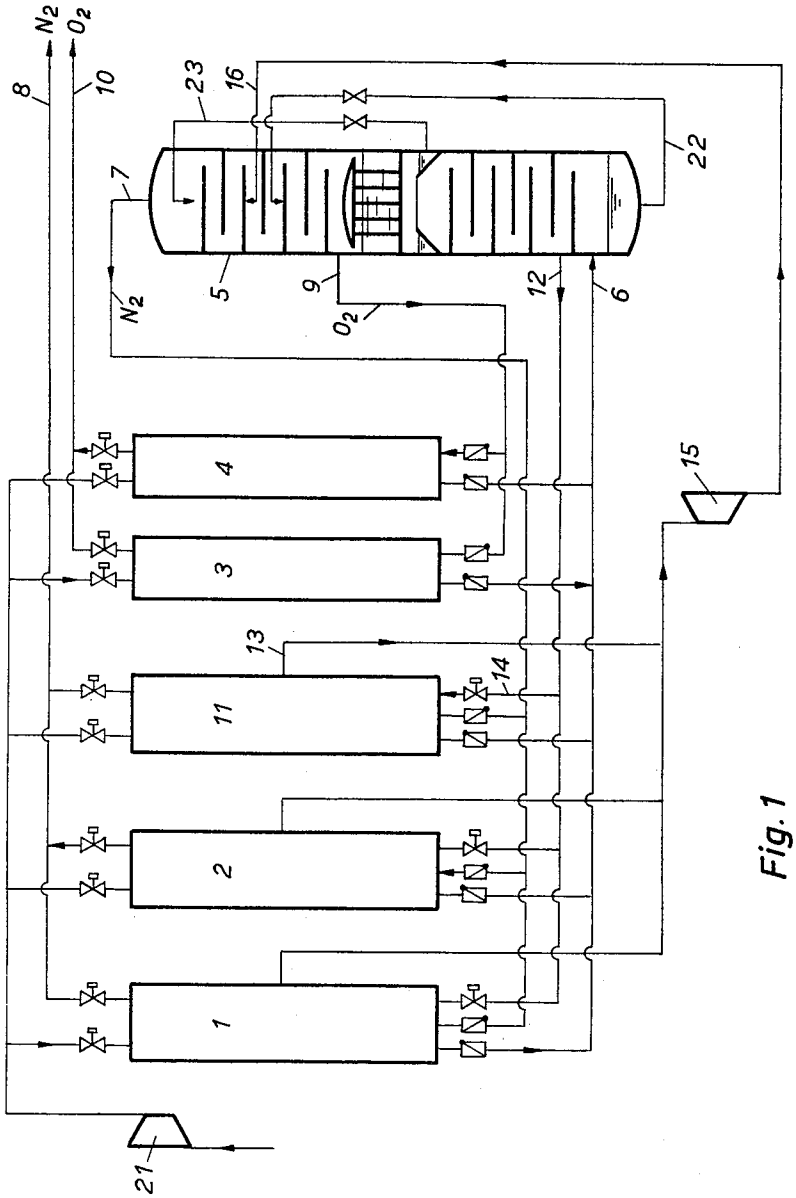

Fig. 1

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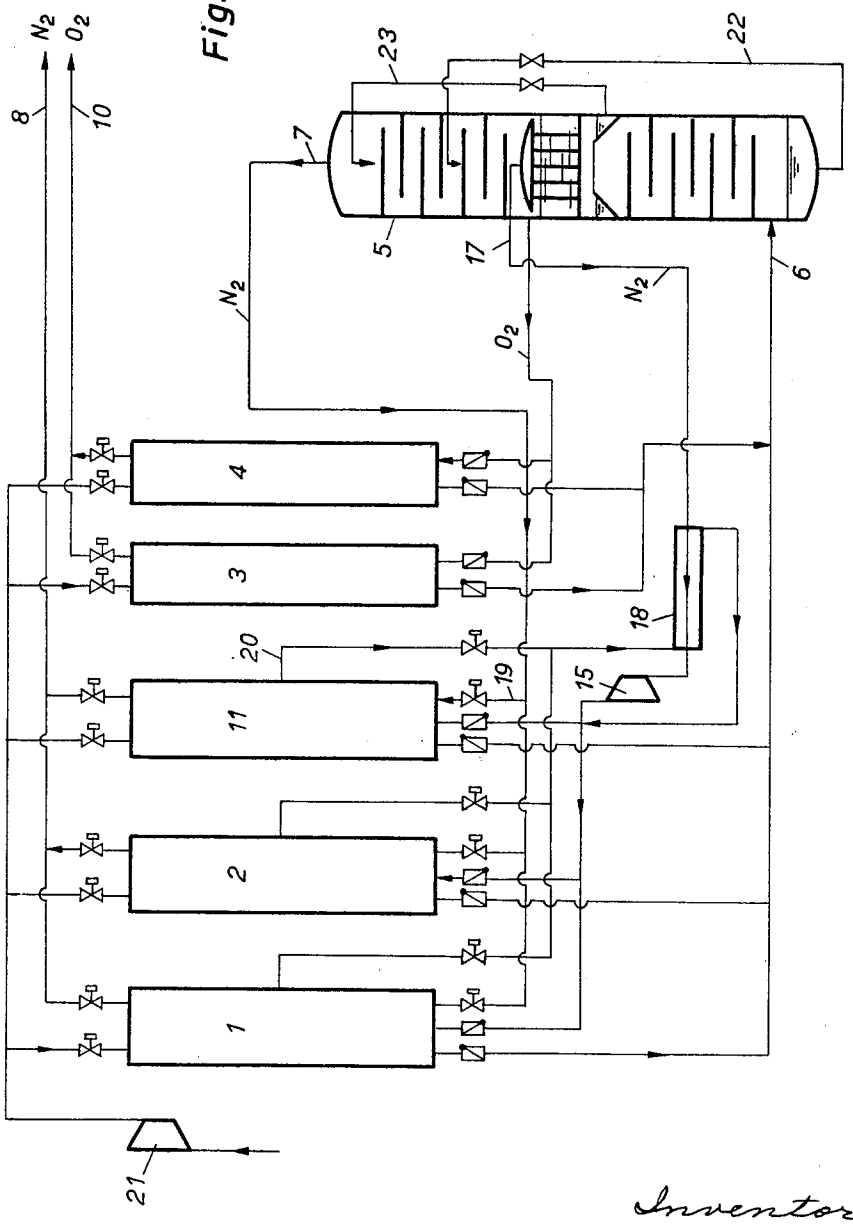
Fig. 2



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PROCESS AND APPARATUS FOR REFRIGERATION BY WORK-PRODUCING EXPANSION

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6 Claims. (Cl. 62—13)

The invention concerns a process and a device for refrigeration by work-producing expansion of a gas (or, gas mixture) which is cooled to a low temperature by means of a regenerator arrangement and thereafter liberated from the condensation products.

The present invention relates in particular to the fact that the refrigeration is effected in connection with a gas separation, which is preferably carried out by low-temperature rectification. As is known, the gas to be expanded generally must be heated again before it enters the expansion machine. Heretofore, special heating coils were used in the regenerator for this purpose, but this expedient reduces the efficiency of the regenerator. Another known possibility was to branch off from the regenerator, at a central point, a partial gas current which had not yet been cooled to the eventual extent, and to use the partial gas current again for work-producing expansion. In this latter case the gas had to be purified additionally by means of adsorbers. Use of such an adsorber, however, requires continuous supervision, and moreover is expensive because of the necessary reversing device and a low temperature tank. If, on the other hand, an intermediate layer of gel is used in the regenerator itself as an adsorbent, a poor carbon dioxide adsorption was attained; and, respectively, increased switching losses were incurred, if the adsorption was effected at low temperature. Besides these disadvantages, the inherent shortcomings of the gel in the regenerator are considered generally as a considerable disadvantage.

The object of the present invention is to eliminate the above described disadvantages and to heat the gas flowing to the expansion machine with a good efficiency of the regenerator and without any special complications.

According to the invention the problem involved in refrigeration by work-producing expansion of a gas (or, gas mixture) cooled to a low temperature by a regenerator arrangement and liberated from the condensation products, e.g., carbon dioxide, water and the like, which gas (or, gas mixture) is heated before the expansion, is solved by the application of an additional regenerator, preferably interposed in the reversing operation of the regenerator arrangement, as a heat source for heating the gas or gas mixture respectively.

According to a special realization of the inventive concept, a part of the crude gas is branched off behind the regenerator arrangement, is conducted through the additional regenerator to be heated therein, and is fed to the expansion device. The expansion device used may be, and preferably is, an expansion turbine.

Another realization of the inventive concept consists essentially in that a separated component of the crude gas, obtained in a gas separating device—in particular, a rectifying column arrangement—is conducted entirely or partly through the additional regenerator and then is fed to the expansion device (e.g., turbine).

The gas, preheated in the above described manner according to the invention, can—unless it is used completely and exclusively for the refrigeration—be added to another gas having a different, preferably lower, temperature before it is introduced into the work-producing expansion device; or, it can be used for the indirect heating of a gas to be expanded.

Two embodiments of apparatus according to the invention are represented, by way of example, in the attached drawing, in which:

FIG. 1 is a schematic representation of a plant, embodying principles of the present invention, for the separation of nitrogen and oxygen from air and illustrating the expansion of a crude gas through an expansion turbine; and

FIG. 2 is a schematic representation of a similarly constituted plant for air rectification, showing a modification wherein one of the separated gases, rather than the crude gas, is expanded through the turbine.

In FIG. 1, 1, 2, 3 and 4 designate two pairs of regenerators through which compressed air is conducted, in known manner, from a compressor 21, for cooling and cleaning. At 5 is denoted a two-stage rectifying column, into which is introduced the air issuing from the regenerator arrangement at 6. In the valve position shown in the drawing, the air traverses the regenerators 1 and 3, while the regenerators 2 and 4 are being traversed by the separation products. Nitrogen is taken from the head of the column at 7 and issues at 8. Oxygen is taken from the column 5 at outlet 9 and issues from the apparatus at 10. The sump liquid of the pressure stage of column 5 is expanded, by way of line 22, into the upper, pressureless stage, while liquid compressed nitrogen flows through line 23 into the pressure-less stage of the column.

According to the invention an additional regenerator 11 is provided, which additional component is included in the reversing cycle of the valves indicated by the usual symbols. A part of the pre-cleaned air is first branched off from column 5 at outlet 12, then conducted by means of lines 13 and 14, to and from the cold end of the regenerator 11 for heating, followed by expansion in a known manner through air expansion turbine 15 and finally introduced at outlet 16 into the rectifying column arrangement in order to meet the cooling requirements of the separating apparatus.

In the operation of the regenerator arrangement according to the invention, the reversal of the regenerators 1, 2 and 11, is so effected that each individual regenerator is first traversed by crude gas, then scavenged by the separation component, and finally used for heating the turbine gas.

FIG. 2 shows by way of example a modified form, wherein not the crude gas (e.g., air) but rather one separation product thereof, particularly nitrogen, is expanded in the expansion turbine. The reference numbers are the same as in FIG. 1 for the identical parts. The air flow through the regenerators 1 and 3 is the same as in FIG. 1. However, in the present case all the air is introduced into the rectifying column 5 at outlet 6. In order to meet the cooling requirements, nitrogen is taken from the head of the lower column at outlet 17 and is conducted through the expansion turbine 15, after which it flows in the represented valve position through the regenerator 2. The heating of the turbine nitrogen is effected, according to this aspect of the invention, by means of a heat exchanger 18 which latter is traversed by a nitrogen current taken from the column 5 at outlet 7 and conducted, by way of lines 19 and 20, through the cold end of the regenerator 11 in order to be heated.

The decision through which end and what parts and zones respectively of the additional regenerator the gas to be heated shall be conducted, depends on the respective conditions encountered. Under certain circumstances it is possible—particularly in an embodiment according to FIG. 2—to significantly reduce the cross-section of the regenerators, e.g., if necessary, to about half. Instead of two large conventional regenerators it is also possible in the arrangement according to the invention to use three regenerators each of half the size.

It is to be noted that the additional regenerator 11 can be used, if the circumstances make the same advantageous, at the same time to produce a product of higher purity. To this end, separate outlets for nitrogen are provided in the regenerators 2 and 11 as indicated, for example, in FIG. 2.

I claim:

1. In a process of refrigerating by the work performing expansion of a compressed gas, the method of heating the compressed gas in an arrangement of at least three cyclically alternated regenerators having heat storing masses before the work performing expansion of the gas, which comprises:

in a first period leading a gas through a regenerator of said arrangement from the warm to the cold end thereof to cool the gas and condense contaminants, in a second period leading a scavenging gas through said regenerator from the cold to the warm end thereof to remove a substantial part of the condensed contaminants from the heat storing mass thereof and in a third period warming the gas to be expanded and removing the remaining condensed contaminants from said heat storing mass by transferring to said gas at least a part of the heat stored in the heat storing mass of said regenerator by passing said gas in direct contact with said heat storing mass.

2. In a process of refrigerating by the work performing expansion of a compressed gas, the method of heating the compressed gas in an arrangement of at least three cyclically alternated regenerators having heat storing masses before the work performing expansion which comprises:

in a first period leading a gas through a regenerator of said arrangement from the warm to the cold end thereof to cool the gas and condense contaminants, in a second period leading a scavenging gas through said regenerator from the cold to the warm end thereof to remove a substantial part of the condensed contaminants from the heat storing mass thereof and in a third period warming the gas to be expanded and removing the remaining condensed contaminants from said heat storing mass by leading it through at least a part of said regenerator by passing said gas in direct contact with said heat storing mass from the cold to the warm end thereof.

3. In a process of separating a gas mixture by rectification at low temperature comprising the work performing expansion of a compressed gas mixture, the method of heating the compressed gas mixture in an arrangement of at least three cyclically alternated regenerators having heat storage masses before the expansion, which comprises:

in a first period leading the gas mixture to be separated through a regenerator of said arrangement from the warm to the cold end thereof to cool the gas mixture and condense contaminants, in a second period leading a separating fraction of said gas mixture through said regenerator from the cold to the warm end thereof to remove a substantial part of the condensed contaminants from the heat storing mass thereof and in a third period warming the gas mixture to be expanded and removing the remaining condensed contaminants from said heat storing mass by leading the gas mixture through at least a part of said regenerator from the cold to the warm end thereof in direct contact with said heat storing mass.

4. In a process of refrigerating by the work performing expansion of a compressed gas, the method of heating the compressed gas in an arrangement of at least three cyclically alternated regenerators having heat storing masses before the work performing expansion, which comprises:

in a first period leading a gas through a regenerator of said arrangement from the warm to the cold end

thereof to cool the gas and condense contaminants, in a second period leading a scavenging gas through said regenerator from the cold to the warm end thereof to remove a substantial part of the condensed contaminants from the heat storing mass thereof and in a third period leading the gas cleaned and cooled in the first period through at least a part of said regenerator from the cold to the warm end thereof to remove the remaining condensed contaminants from said heat storing mass and to warm the gas and expanding the gas to preform work.

5. Apparatus for refrigeration by means of the work performing expansion of a gas in a low temperature system comprising an arrangement of at least three cyclically alternated regenerators, each regenerator including a heat storing mass and having only one steam-conducting cross section and an outlet between its entrance and its exit ends, valved conduit means for leading the gas to be expanded through a first of said regenerators from the warm to the cold end thereof, to cool the gas and to condense contaminants, valved conduit means for leading a scavenging gas through a second of said regenerators from the cold to the warm end in direct contact with the heat storing mass thereof to remove a substantial part of the condensed contaminants from the heat storing mass thereof, valved conduit means for leading the gas to be expanded from the cold end of said first regenerator to the cold end of a third of said regenerators, valved conduit means for leading the gas to be expanded through at least a part of said third regenerator from the cold end thereof to said outlet between the entrance and the exit ends thereof and from said outlet directly to an expansion engine to warm and expand the gas and valve and conduit means to alternate said three regenerators cyclically.

6. Apparatus as defined in claim 5 comprising a two stage rectifying device, conduit means for leading at least a part of a cooled and cleaned gas mixture from the cold end of the first regenerator to the foot of a high pressure column of said rectifying device, conduit means for leading an expanded gas mixture from the exit of the expansion engine to a low pressure column of said rectifying device, conduit means for leading a separating fraction as the scavenging gas from the top of the low pressure column to the cold end of the second regenerator.

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