

1

2,863,294

COOLING AIR PREPARATORY TO LOW TEMPERATURE RECTIFICATION

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This invention relates to the art of cooling air preparatory to low temperature rectification and more particularly to an improved method of effecting heat exchange between air to be cooled to low temperature with simultaneous elimination of atmospheric contaminants such as moisture and carbon dioxide, and a cold air separation product, and to an improved heat exchanger packing material for such heat exchange.

Regenerator packing heretofore customarily used in oxygen plants consists of material known as "aluminum pancakes" which are made of crimped aluminum strip or ribbon about one millimeter in thickness wound in the form of a roll of a diameter substantially equal to the diameter of the regenerator and of narrow width.

Such regenerator filling is described in U. S. Patent Reissue 19,140 of M. Fränkl. Air separation processes employing such regenerators are described in Patents 1,890,646 and 1,970,299 of M. Fränkl. These aluminum rolls or "pancakes" are quite efficient as regenerator packing material but are very expensive.

Since the ribbon pancakes are fragile they split and sag so that they touch each other to create an axial metallic heat conducting path which adversely reduces the thermal gradient through the filling. Also due to the fragility of the pancakes, the cleaning of a regenerator is very difficult and expensive because they cannot readily be removed for cleaning.

Accordingly, it is an object of this invention to provide a less expensive packing for low temperature heat regenerators with substantially no loss in regenerator efficiency. According to this invention rounded pellets of rock-like material stone or quartz having diameters between $\frac{1}{8}$ inch and $\frac{5}{8}$ inch are substituted for the expensive aluminum pancakes without decreasing regenerator efficiency. It has been found that such pellet material used as a regenerator packing minimizes the effect of axial heat conduction due to the large number of discontinuities in the heat flow path from the warm to the cold end of a bed of pellets and also due to the lower heat conduction of the material compared to metal. The pellet material can also readily be cleaned by removing it through a relatively small opening in a regenerator shell, washing it, drying it thoroughly, and returning it to the shell. Also additional pellet material can readily be added to the bed if required whereas with the pancake fillers it is extremely difficult to tighten the filling without damage to the ribbons.

Also according to the invention, either dry or moisture laden air is compressed to a pressure of 10 to 100 p. s. i. g. and at a temperature close to atmospheric temperature, and passed alternately through beds of $\frac{1}{8}$ to $\frac{5}{8}$ inch diameter rounded stone pellets held stationary and substantially immovable in regenerator vessels. The beds of pellets are cooled so that their temperature varies from a temperature close to the liquefaction temperature of

2

air at the one or cold end of the bed to a temperature close to the temperature of the compressed air at the other or warm end of the bed and the air in passing through from the warm to the cold end is deeply cooled preparatory to its low temperature rectification for separation into oxygen-rich and nitrogen-rich products. In its passage through the bed of pellets, the moisture and carbon dioxide of the air are frozen out and deposited in successive zones of pellets. While the air is being cooled by one bed of pellets, a low temperature gaseous air separation product at slightly above atmospheric pressure is passed in an opposite direction through another bed of pellets to cool the pellets and also evaporate deposited carbon dioxide and moisture therefrom. Periodically the flows are exchanged or reversed so that no permanent accumulation of moisture and carbon dioxide occurs, the volume of the cold gaseous product being at least equivalent at the lower pressure to the volume of air cooled. The pellets are preferably held in the beds in the regenerator shells by suitable retaining means at each end of the beds such as by suitably shaped perforated plates and so that the gas flow through the pellet beds is evenly distributed. The regenerator shells have warm end and cold end conduit connections for the respective gases.

Thus a further object of the invention is to provide a method of cooling air preparatory to its low temperature rectification by passing such air through a heat regenerator containing a mass or bed of the cooled pellets.

As used herein, specific diameters or diameter ranges do not imply that the pellet particles are perfect spheres but refer to the largest overall axis of a particle with well-rounded corners and edges. Rounded stone pebbles are satisfactory and beach pebbles and quartz pellets are particularly desirable because of their toughness, and smooth corners and lack of edges.

We are aware that larger pellets have heretofore been used as packing for high temperature regenerators. However, these regenerators employ balls of material having diameters from 1 inch to 8 inches and operate at lower efficiencies of about 85% as compared with 98% to 99% efficiency in "aluminum pancake" packed low temperature regenerators. This lower efficiency, and the attendant high power consumption required to force the gases through the regenerator has discouraged attempts to use pellet packing in oxygen plant regenerators.

As the diameter of the pellet is increased, the drop in gas pressure through the regenerator decreases and the mean temperature difference of the gases increases. Our experiments have demonstrated that a good balance in power costs attributable to these two factors appears to be reached with pebble diameters of $\frac{1}{8}$ to $\frac{5}{8}$ inch. If the pellet diameter is decreased any substantial amount below this range, any improvement in mean temperature difference would be more than outweighed by an increase in gas pressure drop. Power consumption would then increase. Conversely, if the pellet diameter is increased any substantial amount above this range, any improvement in pressure drop would be more than outweighed by the increase in mean temperature difference and power consumption.

A comparison of power consumption between aluminum pancake and pebble type regenerator packings is shown in Table I. The tests were made at constant gas pressure drop by varying the bed depth, thus making the log mean temperature difference between the two gases a measure of packing performance. Heat exchange was effected between moisture laden atmospheric air under about 70 lbs. per sq. in. gauge pressure and dry oxygen vapor at a pressure slightly above atmospheric.

Table 1.—Comparison of regenerator packings

Packing Material	Diameter, Inches	Bed Depth, Inches	Pressure Drop, In. Hg	Log Mean Temp., ° C.	Percent Power Decrease
Aluminum Pancakes.	0.032 (thickness).	86	5.4	4.3	0
Stone Pebbles.....	¼ to ½	66	5.4	4.1	.9

It is seen from this table that the packing efficiency of stone pebbles is comparable to aluminum pancakes, and in fact slightly higher as the former's log mean temperature difference and power requirements are lower.

It is found that stone, quartz or beach pebbles have an advantage over metals in that the axial heat conductivity of the material of the filler mass from the warm end toward the cold end is lower and since each individual pellet undergoes a small temperature change during the periodic reversals, the actual heat storage capacity of the pellets and any variation of this property at widely different temperature levels is of small consequence.

An excellent balance between pressure drop and heat exchange efficiency is obtained by providing the pellet size range between ¼ to ½ inch diameter and the bed depth between about 30 and 120 inches. The smaller bed depth is used with the smaller pellet sizes and with larger pellets the bed depth is preferably larger.

The smaller diameter pellets have another advantage when used for packing in regenerators operating with a relatively low air head pressure, for example 20 p. s. i. g. The usual air head pressure in oxygen gas producing plants is about 75 p. s. i. g., and the outgoing rectification products are passed through the regenerators at slightly above atmospheric pressure. This pressure differential aids the evaporation of water and particularly carbon dioxide into the outgoing products, and permits self-cleaning even when the outgoing product at any packing level in the regenerator is colder than the air which initially deposited carbon dioxide at this level. For example, the usual cold end temperature difference in a 75 p. s. i. g. air head pressure regenerator is about 6° C. for self-cleaning conditions. However, in a 20 p. s. i. g. air head pressure regenerator the previously mentioned advantageous pressure differential is decreased, thus allowing a temperature difference of only 3° C. for self-cleaning conditions. The temperature difference may be reduced to this level by using a larger regenerator packing surface area. While this could be accomplished by using a still smaller but more expensive aluminum pancake packing of greater area, the invention disclosed herein provides a much cheaper solution to this problem in that the small diameter rock-like pellets can provide the desired surface area with equal or better heat exchange efficiency and are also easily and cheaply obtained by proper screening of a random supply of naturally occurring rock-like material. For example it has been found that quartz gravel of certain modern and prehistoric beaches fulfills the requirements and has the added advantage of smooth and rounded surfaces which contribute to minimize the pressure drop in a packed bed of such pebbles.

In short a main advantage of the present invention is

an important reduction in investment and maintenance costs with equal or better heat exchange efficiency than is attained with the Fränkl type regenerators.

This application is a continuation-in-part of our abandoned copending application Serial No. 130,342, filed November 30, 1949.

What is claimed is:

1. In combination with a short regenerator column for cooling air to approximately air rectification temperatures, a stationary bed of non-fragile, heat-accumulating hard and well rounded, rock-like pellet material supportably retained in said regenerator and adapted to minimize the flow of axial heat conduction therethrough, said pellet material having a high degree of voids for the flow of air therethrough and wherein deposition and re-vaporization of the moisture and carbon dioxide in the air occur solely during its passage through the bed of pellets, said pellet material being characterized by substantial inertness to said air flow, said regenerator being filled with said pellet material in sizes ranging between ¼ and ½ inch in diameter to a depth between about 30 inches and 120 inches, the depth of bed and diameter of pellets being adjusted to balance the gas flow pressure drop to the mean temperature difference conditions of the gases, whereby maximum heat exchange efficiency in the cooling of said air and optimum pressure drop conditions in the regenerator are effected, and means of supporting and retaining said bed in the regenerator, said bed being maintained packed between said supporting and retaining means sufficiently to hold the pellets in the bed stationary and substantially immovable.

2. In the art of low temperature air rectification employing a regenerator having alternate reversely flowing gases therein, the improvement comprising establishing in said regenerator a stationary bed of non-fragile, hard and well rounded, heat-accumulating stone pellets having a bed depth between about 30 inches and 120 inches, sizing said pellets to a diameter between ¼ inch and ½ inch, periodically alternating the flow of air to be cooled and rectified and a cold purging gas through said stationary bed, alternately depositing and revaporizing moisture and carbon dioxide in said air solely within the stationary bed of pellets, retaining the bed of pellets stationary during the flow of gases, restricting the interchange of heat in said regenerator substantially solely between said reversely flowing gases and said pellets, and correlating the depth of bed with the rate of flow of said gases to a desired combination of optimum heat exchange efficiency and pressure drop across the bed of pellets.

References Cited in the file of this patent

UNITED STATES PATENTS

1,890,646	Frankl	Dec. 13, 1932
2,121,733	Cottrell	June 21, 1938
2,492,788	Dennis	Dec. 27, 1949
2,560,469	Ogorzaly	July 10, 1951
2,561,720	Alleman et al.	July 24, 1951
2,573,747	Weber	Nov. 6, 1951
2,579,421	Egan	Dec. 18, 1951

FOREIGN PATENTS

276,381	Great Britain	Aug. 18, 1927
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