

United States Patent

[11] 3,599,438

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 [21] Appl. No. **765,282**
 [22] Filed **Oct. 7, 1968**
 [45] Patented **Aug. 17, 1971**
 [73] Assignee **The United States of America as**
represented by the Secretary of the Interior

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[54] **CRUDE HELIUM ENRICHMENT PROCESS**
8 Claims, 1 Drawing Fig.

[52] U.S. Cl..... **62/22,**
23/2, 62/18, 62/23, 62/39, 62/26

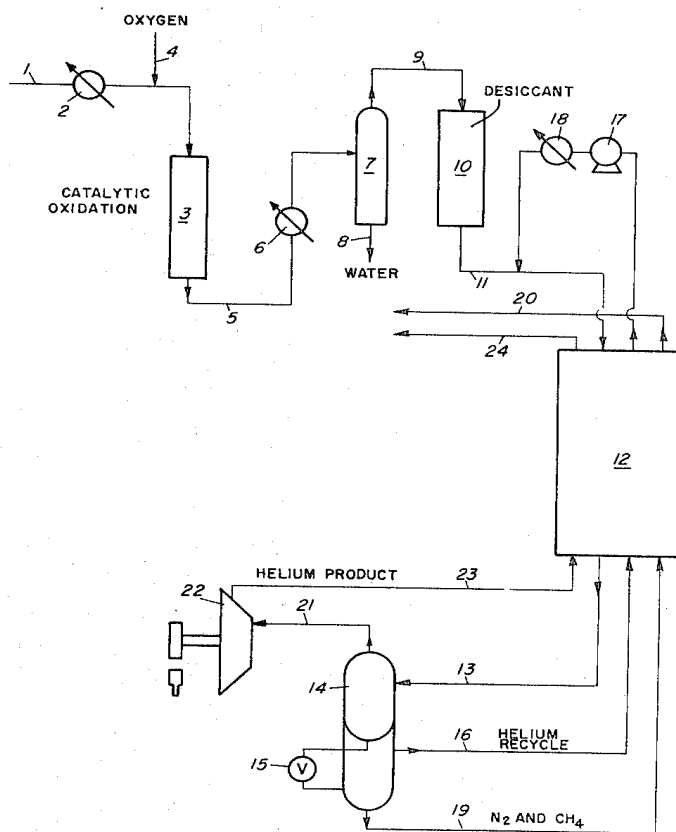
[51] Int. Cl..... **F25j 1/02,**
F25j 3/06

[50] Field of Search..... **62/11, 22,**
23, 24, 27, 28, 39; 23/2

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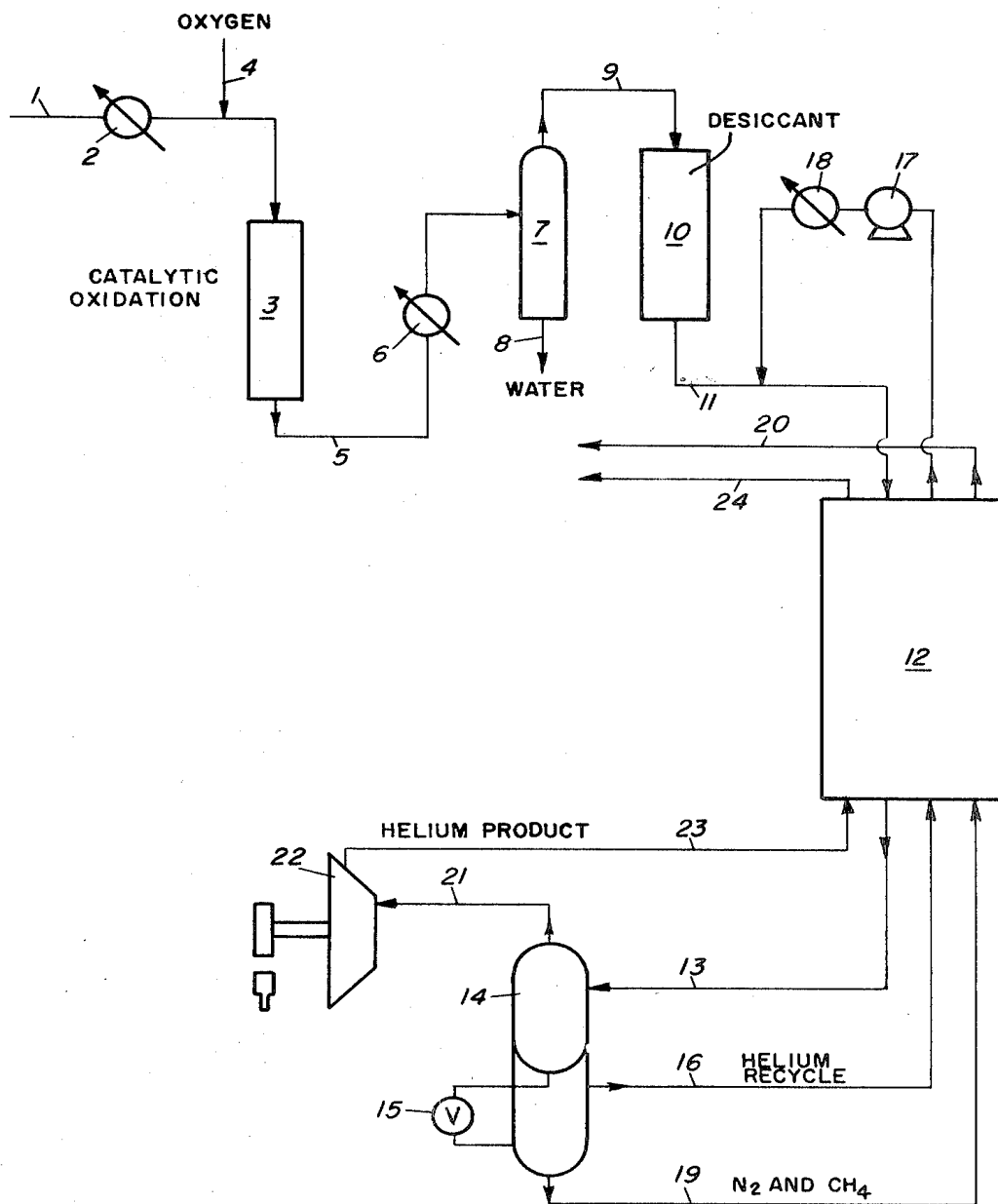
ABSTRACT: A crude helium stream is enriched by liquefaction and separation of contained impurities in a process wherein low temperature level refrigeration is provided by isentropic expansion of the enriched helium stream at its lowest temperature in the process.

This invention resulted from work done by the Bureau of Mines of the Department of the Interior, and the domestic title to the invention is in the Government.



PATENTED AUG 17 1971

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CRUDE HELIUM ENRICHMENT PROCESS

BACKGROUND OF THE INVENTION

Helium occurs primarily as a minor constituent of natural gas and is found principally in a few gas fields in the southwestern United States. Since helium is lost when helium-bearing natural gases are used for fuel, an extensive conservation program has been established to extract helium from these natural gases before the gas is marketed.

Helium is extracted from helium-bearing natural gas by a low temperature gas liquefaction process. The natural gas stream is cooled to a temperature below the liquefaction point of its ordinary constituents but above the liquefaction point of helium. A separation is made of the gas (helium) and the liquid (natural gas). The resulting produce of this separation is called crude helium and generally comprises about 70 percent helium and 30 percent nitrogen. This crude helium is then either further purified to a marketable grade (99.995 percent pure) or is stored for future use.

Crude helium is stored underground in gas reservoirs until required for use. Since few reservoirs of a quality adequate for long term storage of helium without loss are available, it has become important to further enrich the crude helium so as to effectively increase the storage capacity of the existing reservoirs. By enriching the crude helium from 70 percent to 95 percent, for example, capacity of existing storage facilities can be increased by more than one-third.

It has now been found that a crude helium stream may be substantially and economically enriched by a partial liquefaction process wherein low temperature level refrigeration to drive the process is provided by isentropic expansion of the enriched helium stream at its lowest temperature level of the process.

It is an object of this invention to enrich a crude helium stream.

A further object of this invention is to remove impurities from a helium stream without the requirement for an auxiliary low temperature refrigeration system.

DETAILED DESCRIPTION OF THE INVENTION

The invention will be more clearly understood from the following description of a preferred embodiment wherein reference is made to the accompanying drawing.

The FIGURE is a schematic flow diagram of a flow diagram of a preferred embodiment of the process.

Referring now to the FIGURE, a relatively high pressure crude helium stream 1 is passed through preheater 2 and thence into reactor 3. Stream 1 generally contains about 50 to 80 mol. percent helium with the balance being mostly nitrogen. Hydrogen, methane, neon and argon are also generally present in small quantities. Sufficient air or oxygen to completely react with the hydrogen present in stream 1 is introduced into the reactor via line 4. In reactor 3, hydrogen is removed by catalytic oxidation in a manner well known in the art.

Gas is removed from reactor 3 via line 5, is cooled in heat exchanger 6 and is then passed to separator 7 where any liquid water formed by the hydrogen oxidation is removed through conduit 8. From the separator, the gas is then passed through line 9 to drier 10. Drier 10 comprises a bed of desiccant such as activated alumina, silica gel or molecular sieves. Preferably a plurality of drier units are employed in order to allow regeneration of the desiccant without interruption of stream flow.

The dried gas is then passed, via line 11, through heat exchanger 12 where it is cooled by heat exchange with cooler gas flowing countercurrent therewith. Operation of this heat exchanger will be explained in greater detail later. A cooled and partially liquified crude helium stream is removed from heat exchanger 12 and is passed by way of conduit 13 to the first stage of a multistage separator 14 wherein liquid, comprising mostly nitrogen and methane, is separated from helium

gas. Liquid product from the first stage is removed and passed through expansion valve 15 to the second stage of separator 14 which is maintained at a relatively low pressure; generally on the order of 20 to 50 p.s.i.a. Dissolved helium present in the liquid from the first stage flashes under the reduced pressure in the second stage and is removed from separator 14 by means of line 16. This cold gaseous helium stream is passed through heat exchanger 12 wherein it is warmed by heat exchange with the crude helium feed stream and then to recycle compressor 17 where it is compressed to a pressure somewhat exceeding that of the feed stream. Heat of compression is removed in cooler 18 and the recycle stream is then merged with the crude feed in line 11.

Liquid from the second stage of separator 14, comprising mostly nitrogen with only trace amounts of helium, is passed by line 19 through heat exchanger 12 where it vaporizes and is warmed by indirect countercurrent heat exchange with the crude stream. This warm stream is then removed from the system by way of conduit 20.

Gas comprising enriched helium at a pressure substantially equal to that of the crude feed stream is removed from the first stage of separator 14 by way of conduit 21 and is then isentropically expanded to a pressure somewhat below that of the crude feed. Since the helium stream leaving separator 14 will not cool when it is throttled, refrigeration cannot be obtained by Joule-Thomson expansion. Isentropic expansion is performed using an expansion engine 22, which may be either a reciprocating piston or turbine device, in spite of the fact that the gas is at its dew point and liquid forms during the expansion. By limiting liquid formation to less than about 2 percent and preferably to less than about 1 percent, adequate low temperature level refrigeration is obtained to drive the process without interfering with expansion engine operation. Expanded and cooled gas containing a small quantity of liquid is passed via line 23 to heat exchanger 12 where it is warmed by countercurrent heat exchange with the incoming crude stream. This product stream then passes from the system via line 24 for storage, further processing or utilization.

Application of the process to a particular feed stream is shown in the Table. In each case, the stream designation refers to the correspondingly numbered location of the flow diagram.

TABLE.—STREAM DESIGNATION

	1	13	16	19	21	23
Pressure (p.s.i.a.)	1,200	1,200	25	25	1,200	1,000
Temperature (° F.)	75	-306	-314.5	-314.5	-306	-311
Percent liquid	0	28.4	0	99.9	0	0.7
Percent vapor	100	71.6	100	0.1	100	99.3
Composition (mol percent):						
Cl	0.7	0.7	0.1	2.5	Trace	Trace
N ₂	27.4	29.9	65.8	97.5	3.9	3.9
H ₂	70.8	69.5	34.1	Trace	96.1	96.1
H ₂	1.1					

At a feed rate of 18 MMscfd, the recycle compressor 17 requires about 125 BHP, while about 23 BHP is produced by expansion turbine 22. Previous designs for helium enrichment process employed an auxiliary nitrogen refrigeration system to provide low temperature level refrigeration. Power requirements for the auxiliary refrigeration system alone at a feed rate of 18 MMscfd are on the order of 600 BHP.

Crude helium streams having a helium content of about 50 to 80 mol. percent are satisfactory as a process feed stream. Product purity will range from about 90 to 98 mol. percent helium depending upon the feed stream concentration and processing conditions used. Pressure of the crude stream is desirably in the range of about 500 to 2,500 p.s.i. The product gas obtained is sufficiently pure for some industrial uses but, in the example illustrated, enrichment was for the purpose of increasing the capacity of a limited storage area.

What is claimed is:

1. A cryogenic method for enriching a crude helium stream

containing at least about 50 mol. percent helium which comprises:

- a. passing the crude stream in indirect countercurrent heat exchange relationship with colder process streams to at least partially liquify the gaseous impurities curtained in the crude helium stream;
 - b. separating liquid impurities from gaseous helium in a first vapor-liquid separation zone maintained at a pressure substantially equal to that of the crude stream;
 - c. removing an enriched gaseous helium stream containing about 90 to 98 mol. percent helium from the first zone, said gaseous stream comprising a major portion of the crude helium feed stream and being at its dew point, and isentropically expanding the stream to obtain refrigeration to drive the process, to further cool the stream and to liquify a minor portion thereof, and
 - d. passing the cooled partially liquified enriched helium stream derived from the isentropic expansion in countercurrent, indirect heat exchange relationship with the incoming crude stream.
2. The process of claim 1 wherein separated liquid is removed from the first zone and is passed to a second vapor-liquid separation zone maintained at a pressure substantially less than that of the first zone so as to flash dissolved helium from the liquid impurities.

3. The process of claim 2 wherein a vapor stream comprising helium is removed from the second zone, is passed in countercurrent heat exchange relationship with the incoming crude stream and is thereafter compressed and merged with the incoming crude stream.

4. The process of claim 3 wherein helium-depleted liquid is removed from the second separation zone and is passed in indirect heat exchange relationship with the incoming crude stream.

5. The process of claim 4 wherein said isentropic expansion is performed in an expansion engine and wherein expanded gas is thereafter passed in indirect, countercurrent heat exchange with the incoming crude stream.

6. The process of claim 5 wherein liquid formation in the expansion engine is limited to less than about 2 mol. percent of the gas stream being expanded.

7. The process of claim 6 wherein hydrogen contained in the crude helium stream is removed by catalytic reaction with an oxygen-containing gas prior to heat exchange with colder process streams.

8. The process of claim 6 wherein the crude helium stream contains about 50 to 80 mol. percent helium and wherein the isentropically expanded helium stream contains about 90 to 98 mol. percent helium.

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