

March 17, 1925.

1,530,461

A. H. GRAHAM

RECOVERY OF HELIUM

Filed Sept. 25, 1922

2 Sheets-Sheet 1

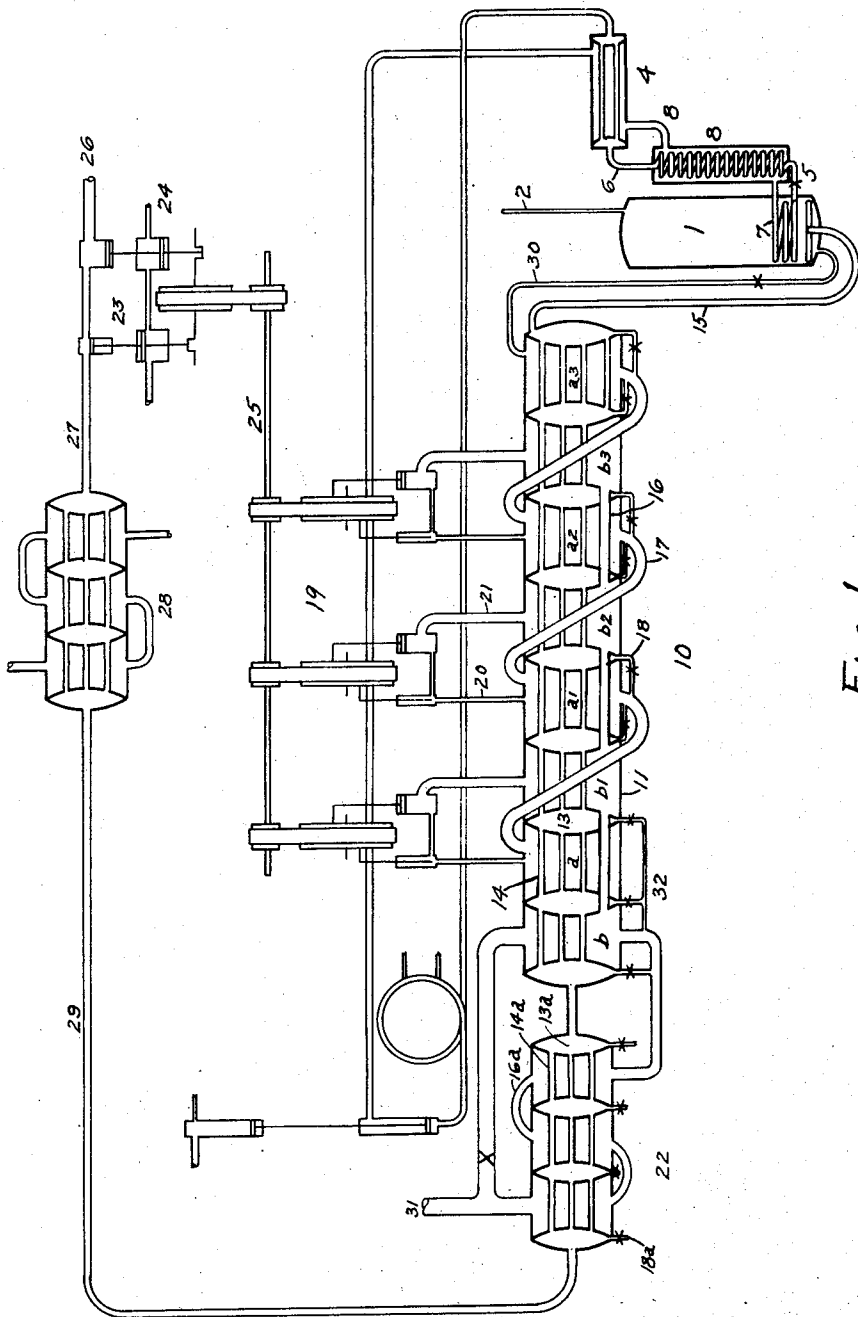


Fig. 1

Arthur H Graham
by
Augustus B Stoughton Atty

March 17, 1925.

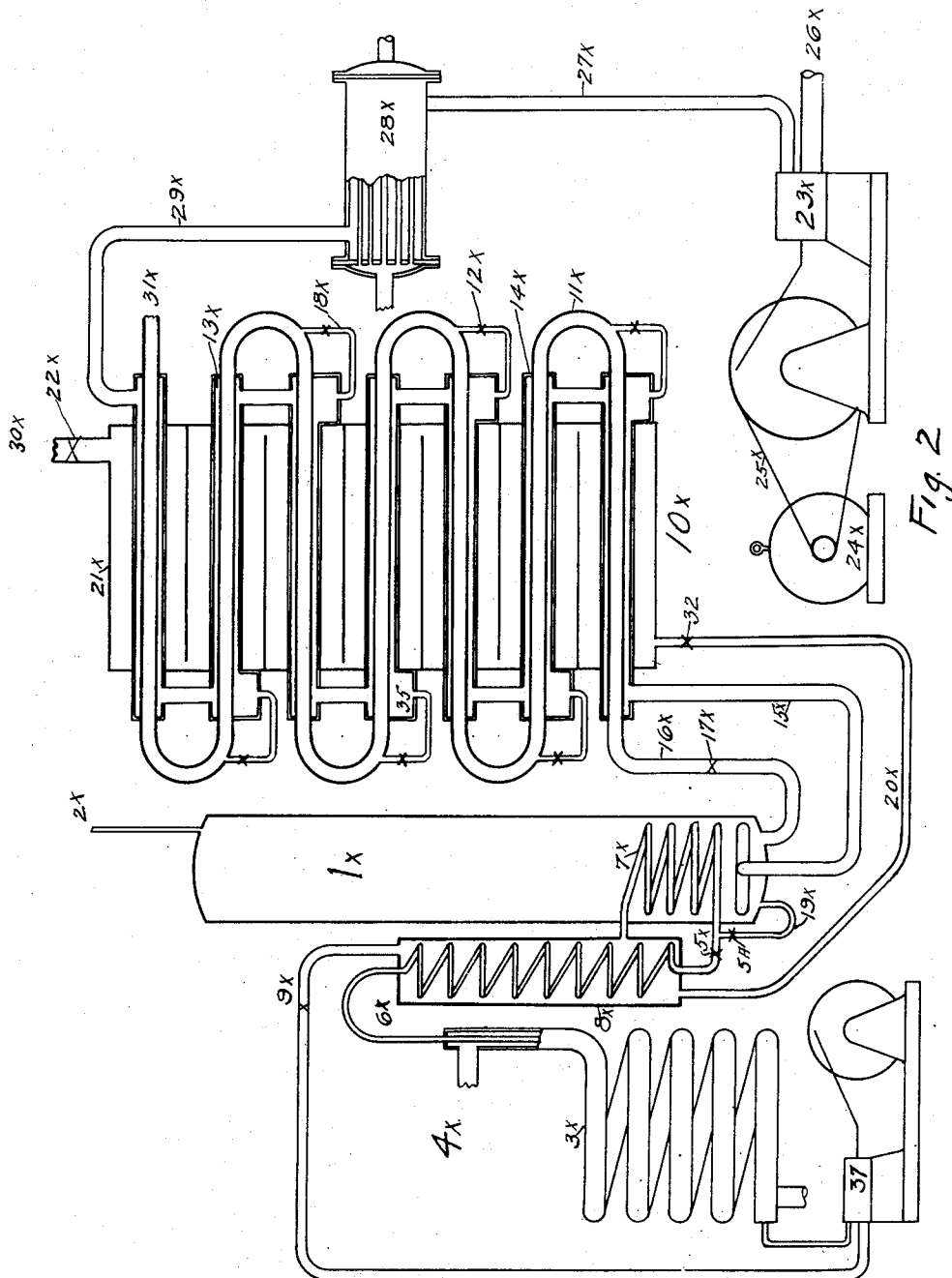
1,530,461

A. H. GRAHAM

RECOVERY OF HELIUM

Filed Sept. 25, 1922

2 Sheets-Sheet 2



Arthur H. Graham

by

Augustus B. Shoultz, Att'y.

Patented Mar. 17, 1925.

1,530,461

UNITED STATES PATENT OFFICE.

ARTHUR H. GRAHAM, OF PHILADELPHIA, PENNSYLVANIA, ASSIGNOR TO GAS EQUIPMENT ENGINEERING CORPORATION, OF PHILADELPHIA, PENNSYLVANIA, A CORPORATION OF DELAWARE.

RECOVERY OF HELIUM.

Application filed September 25, 1922. Serial No. 590,554.

To all whom it may concern:

Be it known that I, ARTHUR H. GRAHAM, a citizen of the United States, residing at Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented a new and useful Improvement in the Recovery of Helium, of which the following is a specification.

The principal object of the present invention is to facilitate the recovery of helium from natural gas and to simplify and improve the process of recovery. Other objects of the invention will appear from the following description of the invention, and the invention will be claimed at the end hereof, but will be first described in connection with the accompanying drawings forming part hereof and in which—

Figure 1 is a view illustrating diagrammatically and schematically one form of apparatus for the practice of the invention, and

Fig. 2 is a similar view illustrating a modification.

The practice of the method of the invention may be briefly said to include three principal steps or operations: First, total liquefaction of substantially all of the constituents of the gas other than helium; second, removal of the uncondensed helium at a low temperature; and third, vaporization of the liquid in stages or fractionally at approximately the pressure under which it was condensed, thereby similarly effecting condensation of nearly a like quantity of incoming gas so that a material economy is effected and the recovery of helium increased.

The invention will be further described in connection with the accompanying drawings having particular reference to Fig. 1 in which there is illustrated apparatus of which the heat exchanger shown at the bottom of the sheet is in sectional elevation and in which the apparatus shown at the upper part of the sheet is principally in sectional plan, the view being thus distorted for the sake of clearness in explanation. The separator 1 is a part of a region of refrigeration at which helium will not liquefy and from which it is withdrawn at low temperature by way of the outlet 2. In this region substantially all of the other constituents of the natural gas will liquefy.

The refrigerating apparatus generally indicated at 4, is a means for producing the region of refrigeration at 1 by the use of air or nitrogen liquefied at high pressure which reaches the expansion valve 5 by way of the path 6, and then traverses the coil 7 and leaves by the path 8. This region of refrigeration includes a heat exchanger, generally indicated at 10. The heat exchanger shown may be described as follows: 11 is a shell subdivided by tube sheets, arranged in pairs with space 13 between the plates of each pair, into high and low pressure chambers arranged in alternation. The chambers a , a^1 , a^2 , and a^3 are high pressure chambers and the chambers b , b^1 , b^2 and b^3 are low pressure chambers. The gas passes by tubes 14 connected with the spaces 13 between the tube sheets and extending across the chambers, and the gas finally reaches the separator 1 by the connection 15. There are tubes 16 which connect the low pressure chambers and there are what may be called jump pipes 17 which connect the lower portions of each of the high pressure chambers with the next high pressure chamber in the series. These jump pipes 17 are also in communication with the spaces 13 between the pairs of tube sheets by way of the connections 18. The inlets of expanders 19 are connected with the high pressure chambers as by 20, and the outlets of the expanders are connected as by 21 with the low pressure chambers. 22 may be said to be an extension of the heat exchanger 10, and is itself a heat exchanger or cooler and the parts of it which correspond with the heat exchanger 10 are marked with the same numerals, having added thereto the exponent "a". 23 is a compressor which is driven by power from a suitable source of power applied as at 24, and also by such power as is available from the expanders 19 with which it is geared as by gearing 25.

Natural gas entering at 26 is subjected to the action of the compressor 23 and then passes as by 27 through cooler 28, through pipe 29, through cooler or heat exchanger 22, and through tubes of heat exchanger 10 to separator 1, from which the liquid minus substantially all of the helium passes by pipe 30 back through the heat exchanger 10 in a manner that will be presently de-

scribed, the products of vaporization or gas escaping at 31.

From the foregoing it will be evident to those skilled in the art that a stream of natural gas under pressure in traversing the tubes of the cooler 22 exchanges its heat, or some of it, with the medium surrounding those tubes, and such vapor as may condense is withdrawn by way of the connections 18^a, and generally speaking, the same action takes place in the tubes of the heat exchanger 10, so that finally the gas at a very low temperature and under pressure is subjected to the described action of the separator 1, and the helium, or substantially all of the helium, is led off at 2 at a low temperature. The liquid returning by 30 enters the high pressure chamber a^3 and is distributed in intimate contact with the tubes 14 therein, and a part of it evaporates, and the whole mass together with liquid condensed out of the natural gas between the pairs of tube sheets and escaping therefrom by the connection 18 is passed by the jump pipe 17 to the high pressure chamber a^2 . In the high pressure chamber a^2 a portion of the liquid is vaporized and the resulting gas is passed through an expander 19 and back to the low pressure chamber b^3 where there is an exchange of sensible heat from the incoming gas, and then passes by 16 to the low pressure chamber b^2 and the remaining portion of the liquid passes by jump pipe 17 to high pressure chamber a^2 , and the described operation is repeated through the high and low pressure chambers and apparatus shown in the drawing progressively from the right towards the left. The number of repetitions is not material and may be increased or diminished and a description of one such operation is believed to be sufficient.

The chambers in the apparatus 22 at the left in the drawing are cooled by returning low pressure gas and by the liquid which has condensed from the incoming natural gas and which is withdrawn from spaces 13 by the connection 32.

From the foregoing description it appears that, generally stated, there is established a region of refrigeration at which helium will not liquefy and from which it is withdrawn at low temperature and at which substantially all the other constituents of the natural gas will liquefy. I do not desire to define the exact extent of that region because it may vary in different cases, but what I mean in a general way is the region included by the apparatus 10. Through that region of refrigeration I lead a supply of natural gas under pressure and I effect heat exchange between that incoming supply of gas and the outgoing gas and its liquid constituents, and this I do by vaporizing the liquid constituents of the outgoing gas along

with like constituents condensed and separated from the incoming gas in stages approximately the pressure under which they were condensed, thereby effecting condensation of nearly a like quantity of incoming gas. The vaporization of the liquid takes place in stages in the sense that the vaporization is fractional. The vapor or gas resulting from the vaporization is withdrawn, expanded and cooled and the sensible heat of the expanded gases is used at low pressure, and this operation is repeated.

I believe that the described vaporization of the liquid in such a way that it will absorb the larger part of the heat of condensation of the incoming gas is new, and I also believe that it is new to provide the connections indicated at 18 and the jump pipes indicated at 17, so that it is an important feature of the invention that liquid from the incoming gas is taken from high pressure chambers and put as liquid into other high pressure chambers, by-passing the low pressure chambers, in contra-distinction to the customary practice in which such liquid was passed from a high pressure chamber directly into a low pressure chamber.

It may be said that the final refrigeration or liquefaction of the condensable gases in the vessel 1, is effected by expanding liquid nitrogen or air, and that the liquefaction of the other fractions of the incoming gas is accomplished according to equilibrium by fractional vaporization of the outgoing liquid in suitable contact with the incoming supply and at pressures and temperatures substantially the same at like points of condensation and vaporization, and it may also be said that by withdrawing the condensate from the incoming supply and adding it in stages to the outgoing gas supercooling of the condensate is avoided.

As shown in Figure 1, this is accomplished by providing high pressure chambers a , a^1 , a^2 and a^3 , in the return circulation, but in Fig. 2 these chambers are omitted as are also the expanders 19. However in certain essentials the operation is the same. In Fig. 2 the parts which correspond to the parts shown in Fig. 1, are marked with the same numerals with the addition of the exponent "x," and in Fig. 2, 10^x is a region of refrigeration consisting of a countercurrent interchanger wherein 11^x is a tube or series of tubes arranged so as to be surrounded by a larger tube 14^x with space 13^x between the tubes which space 13^x communicates with the chambers 35 located at one end of tubes 14^x. Pipes 18^x connect chambers 35 with tubes 11^x. 21 is a chamber enclosing the greater portion of tubes 14^x.

Gas which has been previously treated for the removal of water vapors and carbon dioxide enters at 26^x where it is compressed by compressor 23^x and enters wa-

ter cooler 28* by pipe 27*. Pipe 29* conducts cooled gas to tubes 14* where it travels through the spaces 13* to pipe 15* which leads to the separator 1*. Here the gas comes in contact with a coil 7* which is cooled by liquid air or liquid nitrogen supplied by refrigeration plant 4*. Practically all of the gas except the helium, is liquefied at this point and the helium is removed through pipe 2*. The liquefied gas is returned to 10* through pipe 16* where there is an exchange of sensible heat from the incoming gas and continues through tubes 11* until a region is reached wherein the temperature causes evaporation according to the vapor pressures of the gas. At these points fractional condensation will take place within the spaces 13*, thereby utilizing the latent heat of evaporation of the gas in tubes 11* in condensing approximately a like amount of gas in spaces 13* until equilibrium between the amount of vapor and gas present in spaces 13* and in tubes 11* has been reached. The liquids so condensed in spaces 13* will collect in chambers 35 and will be removed by pipes 18* to tubes 11* where these liquids will exchange their sensible heat and heat of vaporization with the gas in spaces 13* thereby continuing the process of cooling and condensing the gas in spaces 13*. The gas will travel through the series of tubes 11* until it reaches approximately the temperature of the incoming gas. It will leave the region 10* by pipe 31* at substantially its original pressure. By this process, after suitable temperatures have been reached and the fractional condensation of the gas is taking place throughout the system and the system is in such condition that practically the only constituent of the liquid in the bottom of separating chamber 1* is nitrogen, compressor 37 may be shut down, valves 9* and 5* closed, valves 22* and 32 opened and part of the liquid nitrogen from the bottom of separating chamber 1* can be removed by pipe 19* to throttle valve 5*, where it will be expanded into coil 7* and will leave coil 7* through chamber 8*, passing by pipe 20* to nitrogen chamber 21* where it will exchange its sensible heat with that of the gas in spaces 13*, and will finally lead out of the system at outlet 30*, thereby increasing the heating value of the gas by removing some of the nitrogen.

Without limiting the invention I may say that pressure ranging from 19 to 25 atmospheres, more or less, will beneficially affect the percentage of helium recovered. In the auxiliary cycle generally referred to in the drawings at 4 and 4*, air or nitrogen are equivalents and when nitrogen is referred to in the claims the intention is to include air. It may be said that the temperature of the liquid condensate from the

natural gas is lowered by the auxiliary cycle and that the gaseous helium is withdrawn at substantially the pressure and temperature of its minimum solubility in the liquid present.

From the foregoing description it is evident that I have provided a method of separation of helium from the liquefied natural gas which eliminates the use of any of the usual forms of fractionating or rectifying columns, employing the use of plates with bubble caps or like devices and providing a definite reflux of the components of highest vapor pressures and that my method of operation as described, is in emphatic contrast-distinction to methods employing usual fractioning or rectifying columns or both.

It will be obvious to those skilled in the art to which the invention relates that modifications may be made in details of construction and arrangement and procedure without departing from the spirit of the invention which is not limited as to those matters or otherwise than as the prior art and the appended claims may require.

I claim:

1. In the recovery of helium from natural gas the improvement in the step of fractionally condensing constituents other than helium of the incoming natural gas by heat exchange with the outgoing liquid condensate which consists in vaporizing the respective constituents of the condensate under temperature and pressure conditions substantially like the temperature and pressure conditions under which they were condensed, substantially as described.

2. In the recovery of helium from natural gas the improvement in the step of fractionally condensing constituents of the incoming natural gas by heat exchange with the outgoing liquid condensate which consists in vaporizing the respective constituents of the condensate under conditions substantially like the conditions under which they were condensed, and permitting the outgoing liquid condensate to pick up constituents condensed from the incoming natural gas at or near the points of condensation.

3. In the recovery of helium from natural gas the improved step which consists in effecting heat exchange by fractionally condensing and fractionally evaporating like constituents of the incoming and outgoing supplies under substantially the same conditions of temperature and pressure, substantially as described.

4. The process of recovering helium from natural gas which consists in supplying and expanding a suitable liquid to establish a region of refrigeration at which helium will not liquefy and from which it is withdrawn at low temperature and at which substantially all other constituents of the gas will liquefy, leading and in steps condensing a

stream of natural gas containing helium under pressure through said region, and effecting heat exchange between said stream of gas and liquid constituents by vaporizing the latter in stages at approximately the pressure under which they were condensed, thereby effecting condensation of nearly a like quantity of incoming gas.

5. In the art of recovering helium from natural gas the improved step which consists in effecting heat exchange between the natural gas under pressure and the outgoing liquid by evaporating the liquid at high pressure in alternate stages, and expanding and cooling the gas evaporated from the liquid and applying its sensible heat at intermediate stages.

6. In the recovery of helium from natural gas the improved step which consists in effecting heat exchange between the incoming gas and the outgoing liquid condensate by vaporizing the condensate in stages under temperature and pressure conditions substantially like the temperature and pressure conditions under which it was condensed.

7. In the process for the recovery of

helium from natural gas in which the constituents other than helium are condensed and the helium drawn off in a region of refrigeration, the improvement which consists in producing the temperature of refrigeration in said region by an auxiliary cycle of liquid nitrogen and in vaporizing the returning liquid in heat exchange relation with the incoming supply of gas at temperatures and pressures substantially identical with the temperatures and pressures at which they were condensed.

8. In the process for the recovery of helium from natural gas in which the constituents other than helium are condensed and the helium drawn off in a region of refrigeration, the improvement which consists in producing the temperature of refrigeration in said region by an auxiliary cycle of liquid nitrogen and in fractionally vaporizing the returning liquid in heat exchange relation with the incoming supply of gas at temperatures and pressures substantially identical with the temperatures and pressures at which they were condensed.

ARTHUR H. GRAHAM.