

UNITED STATES PATENT OFFICE.

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SEPARATION AND LIQUEFACTION OF GASES.

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This invention relates to the separation and liquefaction of gases and proposes a method and means for treating a mixture of gases whereby the segregation of one of the gases from said mixture is accomplished by liquefying, and whereby the expanding gas is utilized to perform external as well as internal work.

The principal object of this invention is identical with that set forth in my copending application filed January 11, 1927, Serial No. 160,446, that is, to bring successive portions of a progressively flowing column of the gaseous mixture into heat-interchanging relationship, under such conditions of high pressure as may be naturally encountered, and at such temperature to the one portion as will liquefy one of the gaseous constituents of the mixture at that pressure, provision being made for a pressure drop between the successive portions of the mixture at atmospheric or any other convenient pressure, whereby the critical temperature is lowered proportionately to the pressure drop, the conditions of liquefaction being thus continued down into the realms of low pressure so that a continuous supply of liquefied gas is produced and maintained available for use at low pressure, and whereby the gas is used for both internal and external work.

Other objects of the invention will appear as the description of the following illustrative and largely diagrammatic embodiment of the apparatus proceeds, by which the method which constitutes one phase of the invention may be practised.

In the drawings, the one figure represents a side elevation, partly in section, of the complete apparatus illustrating this invention, and in which the numeral 1 designates a conduit, the end 2 of which is assumed to be in communication with a mixture of gases under high pressure. In the present instance, the invention is contemplated in connection with the segregation of methane from natural gas, and the end 2 of the conduit 1 may be connected directly to a high pressure gas well, or to a compressor in case the natural pressure is not sufficiently high to accomplish the purpose of this invention. The conduit 1, as shown, passes successively through the serially connected counter-current interchangers 3 and 4, of which there may be any number, between which interchangers are mounted traps 7 and 8. The purpose of these

traps is to collect any vapors of the gaseous mixture which may have become condensed through the cooling action of the interchangers. It is very important that the gaseous mixture be thus dried before the final liquefaction of the methane to prevent the deposit of frost on the interior surface of the conduits especially in that region in which the temperature approaches the critical temperature of the methane.

The conduit 1 is preferably formed with a vertical limb or pipe 11 which passes through the vertical interchanger or chamber 12. The pipe 11 communicates with the interchanger by means of the stator 13 mounted in the chamber 12' and provided itself with a chamber 14 and with the directing nozzles 15. The upper part of the chamber or interchanger 12 is in communication by means of the pipe 15' with the series of interchangers 4 and 3. The process of this invention may be fully carried out by the apparatus which has now been described, but the drawing illustrates a branch conduit 16 communicating with the vertical pipe 11 of the conduit 1, said branch conduit providing a duplicate set of interchangers and traps for alternative use when the first described series of interchangers and traps is isolated or cut off for the purpose of repair, or for any other reason. The valves as 17 and 17' are employed for connecting either the conduit 1 or the branch conduit 16 into and out of operative relation with the pipe 11.

Mounted for rotary movement and vertical adjustment in the lower chamber 12' is a shaft 18 carrying the rotor 19, said rotor being mounted within the chamber 12', while upon the lower end of the shaft externally of said chamber 12' is an electric generator 20, the same being indicative of any driven element that it may be desired to operate through the medium of the present turbine. To adjust the rotor relative to the stator, the screw 21 is supported in the base 22 and extends within the shaft 18, so that the hand wheel 23 mounted on the screw can be rotated to thus elevate or lower the shaft, and consequently, the rotor 19 and generator 20. This action permits the nozzles 15 of the stator 13 to direct the operating gases flowing from the pipe 11 to act upon the rotor 19 and in consequence rotate the generator 20.

Connected to the chamber 12' is a draw-off

valve 24, the purpose of which will presently appear.

In the operation of my invention, the gas under high pressure passes through the conduit 1 in the direction of the arrows, the moisture of any gaseous constituents which are liquefiable at relatively high temperatures being condensed and retained by the series of traps 7 and 8. The gaseous mixture then proceeds into the pipe 11, the unliquefied or cold gases expanding from high pressure to atmospheric, or some other lower convenient pressure through the nozzles 15 of the stator 13.

Now since the gaseous mixture in the vertical pipe 12 is under high pressure and is conveniently subjected to counter-current cooling of the regenerative type, the temperature of the gas to be separated from the mixture will ultimately fall to a point at which liquefaction will take place within the pipe 11. Also, as this cool gas, vapor, vapor liquid mixture and any liquid condensate thereof expands through the nozzles 15 into the lower chamber 12' of the interchanger 12, vapor and liquid at atmospheric pressure will result. The temperature of the vapor liquid mixture in the interchanger 12 will be that of boiling point of the liquid at atmospheric pressure. Now this temperature is very much lower than that in the conduit 11 which is the critical temperature at the high pressure existing in said conduit. Therefore, there will be a decided interchange of heat between the conduit 11 and the interchanger 12, liquefying the liquid of said vapor in the interchanger 12. Since the latent heat of condensation of the vapor in the conduit 11 due to its high pressure is less than is the latent heat of vaporization of the liquid in the interchanger 12, the latter liquid will tend to accumulate in quantity in the chamber 12 below the turbine, so that it can be drawn off at a fixed rate through the valve 24. Also as the quantity of such liquid increases it will rise above the turbine and in the interchanger 12 to some point determined by the combined effect of the rate of ebullition in the interchanger 12 and the rate at which liquid is drawn off through the valve 24.

Due to the regenerative cooling used, the temperature of the gases would fall to a liquefying point in the collecting chamber 12', and gradually accumulate there until the turbine rotor is reached. Then the turbine rotor 19 is lowered so that the expanding gas cools by internal work only. The liquid continues to rise until it not only fills the collecting chamber 12', but partially the lower end of the interchanger 12. Thus, at this time, the liquefying tube 11 containing the high pressure air is completely surrounded by liquid methane or other gases at a lower temperature and pressure. Eventually, the liquid will form and accumulate in the lique-

fying pipe 11 so that the material toward the bottom of said pipe will be at approximately the same temperature as that in the chambers 12' and 12, so that in passing through the nozzles 15, no expansion will take place, but rather liquid at high pressure will flow into liquid at low pressure without the attendant formation of vapors.

Therefore, liquefaction in the tube or pipe 11 occurs by virtue of the exchange of heat caused by the differences in latent heats at high and low pressures. Since the latent heat at low pressure is controlled by the temperature of evaporation, at that pressure heat will tend to flow from the high pressure tube 11 to the low pressure chamber 12, causing the liquid there to boil, as particularly set forth in my above referred to copending application.

Owing to the fact that both internal and external work is performed in the initial stages of liquefaction, the temperature drop per pound of gas flowing through the nozzles 15 will be greater than if only internal work was used. This greatly accelerates the speed at which refrigeration can be attained, and thus reduces the heat losses to the outside atmosphere, and consequently, means a reduction in the initial pressure required. Thus a saving in the operation and first cost results from the present arrangement.

Also, since the heat removed from the high pressure air when in full operation is by interchange and not by expansion, the capacity per unit output will be very much increased.

While attention has been directed chiefly to that gas of the mixture which it is intended to segregate by liquefaction, it is to be understood that these constituents of the gaseous mixture which are unliquefiable at the low temperature attained by the interchanger 12 will pass upwardly along with the vapor of ebullition of the liquid in said interchanger, the cold gases and vapor flowing through the series of interchangers 4 and 3 inclusive by way of the pipe 14, in a counter-current direction.

I claim:—

1. An apparatus for segregating a gas or a mixture of gases by liquefaction of said gas, including pressure and expansion conduits arranged in heat-interchanging relationship and providing an enlarged accumulating chamber, a stator mounted in said chamber and forming a plurality of restricted passages between the two conduits to produce a pressure drop between a gaseous mixture admitted under pressure to the pressure conduit, and passing through said stator expansively into the expansion conduit, the passages through the stator being of such a size as to produce a temperature below the critical temperature of one of the components of the gaseous mixture in the ex-

pansion conduit, and a rotor mounted in said accumulating chamber to be acted upon by the gaseous mixture as it leaves the stator.

2. An apparatus for segregating a gas from a mixture of gases by liquefaction of said gas, including a pressure conduit, an interchanger surrounding the pressure conduit and provided with an enlarged lower end, a stator mounted at the lower end of the pressure conduit and in the enlarged end of the interchanger, and a rotor mounted in the enlarged end of the interchanger and in cooperative relation to the stator.

3. An apparatus for segregating a gas from a mixture of gases by liquefaction of said gas, including a pressure conduit, an interchanger surrounding the pressure conduit and provided with an enlarged lower end, a stator mounted at the lower end of the pressure conduit and in the enlarged end of the interchanger, and a rotor adjustably mounted in the enlarged end of the interchanger and in cooperative relation to the stator.

4. An apparatus for segregating a gas from a mixture of gases by liquefaction of said gas, including a pressure conduit, an interchanger surrounding the pressure conduit and provided with an enlarged lower end, a

stator mounted at the lower end of the pressure conduit and in the enlarged end of the interchanger, a shaft journaled for longitudinal adjustment and for rotary movement in the lower end of the enlarged end of the interchanger, a rotor mounted in the enlarged end and connected to said shaft, and a driven element upon said shaft exteriorly of said interchanger.

5. An apparatus for segregating a gas from a mixture of gases by liquefaction of said gas, including a pressure conduit, an interchanger surrounding the pressure conduit and provided with an enlarged lower end, a stator mounted at the lower end of the pressure conduit and in the enlarged end of the interchanger, a shaft journaled for longitudinal adjustment and for rotary movement in the lower end of the enlarged end of the interchanger, a rotor mounted in the enlarged end and connected to said shaft, a driven element upon said shaft exteriorly of said interchanger, and manually operable adjusting means for varying the relationship of the rotor to the stator.

In testimony whereof I have hereunto set my hand.

WILLIAM SPENCER BOWEN.