

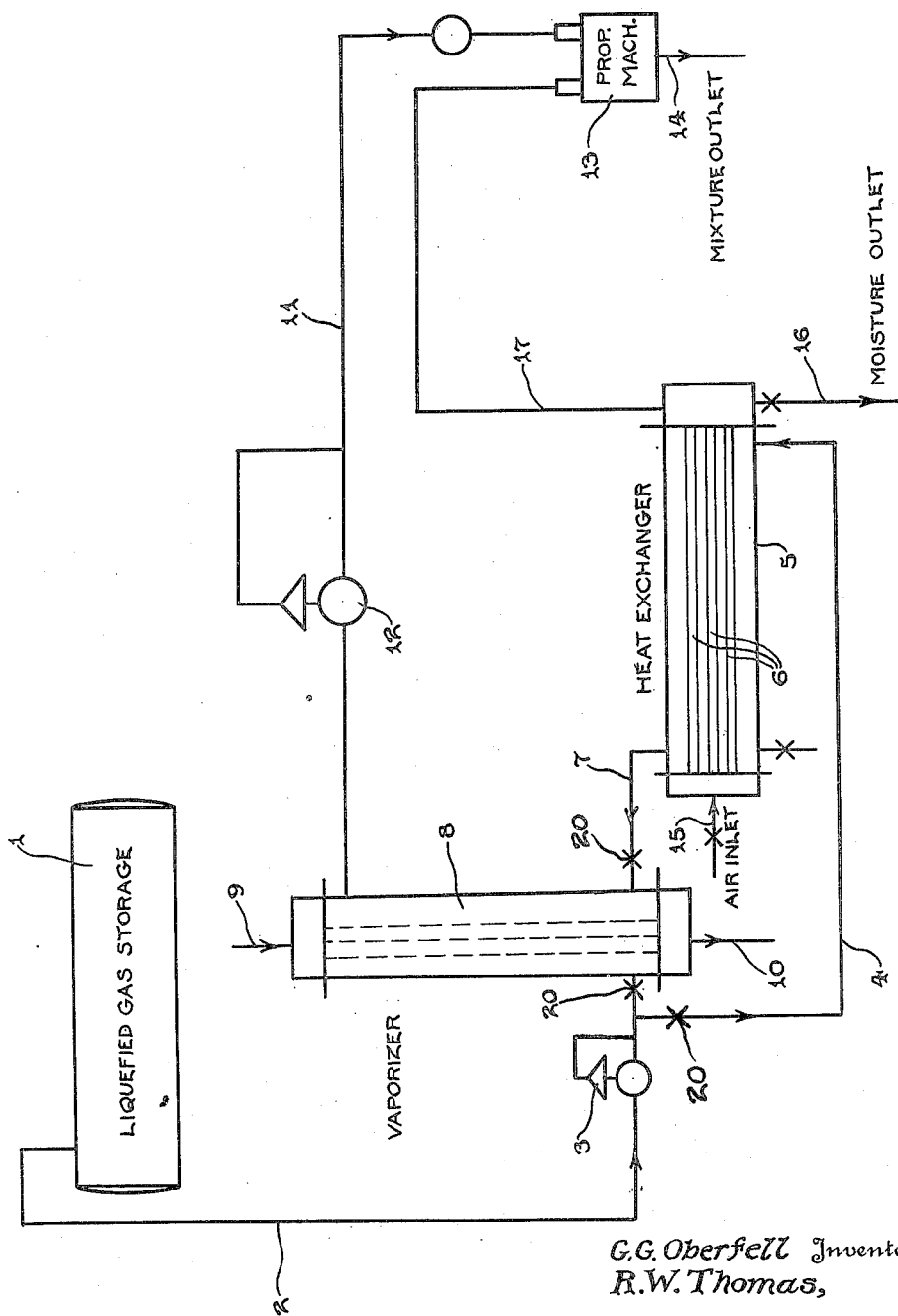
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DEHYDRATION OF AIR OR THE LIKE AND GASEOUS MIXTURES

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DEHYDRATION OF AIR OR THE LIKE AND GASEOUS MIXTURES

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This invention relates generically to the dehydration of gases such as air, and specifically to the dehydration of air to be used in an air and gas mixture, by heat exchange with the gas employed in the mixture.

In the manufacture of an air-gas mixture for domestic or industrial consumption, it has heretofore been the practice to use mechanical or indirect heat or refrigeration for the dehydration of air used in the mixture. The need for dehydration is evident when the temperature of the air entering the pipe lines is substantially different from the temperature of the pipe line itself, or the surroundings. A sudden change in temperature causes a condensation which is distinctly harmful to the use of the mixture. For instance, if the air is not dehydrated, and it carries a substantial percentage of moisture, this moisture, on condensing, is not alone liable to clog the pipe lines, but may freeze and cause rupturing of the lines. Furthermore, when the air is not dehydrated, it necessitates drips and the cost of pumping the drips. By the present invention, all the drips and the cost of pumping the same will be eliminated.

The present process differs from the ones heretofore known, in that the latent heat of vaporization of the liquefied hydrocarbon gas to be used in the mixture, is used in heat exchange relation with the air to dehydrate the latter before the air enters the mixture. One of the advantages of such a system resides in the fact that the heat exchange relation of the hydrocarbon gas and the air in the dehydration process, provides for some of the heat of vaporization necessary in the vaporization of the fuel.

From the foregoing, it will be manifest that the primary object of the invention is to provide a novel system in which the hydrocarbon gas to be used in an air-gas mixture is employed in dehydrating the air used in such mixture.

With the foregoing objects outlined and with other objects in view which will appear as the description proceeds, the invention consists in the novel features hereinafter described in detail, illustrated in the accom-

panying drawing, and more particularly pointed out in the appended claims.

The drawing shows a diagrammatic view of one form of apparatus for practicing the method.

It has heretofore been proposed to utilize light hydrocarbons boiling below 100° F. for the purpose of diluting the air forming an air-gas mixture. For example, one proposal includes the mixing of substantially pure butane with air, in the proportions of about 15% butane vapor and about 85% air by volume. In making such mixtures, it has been necessary to dehydrate the air to eliminate the objections above mentioned. If the present invention is used in such a system, the light hydrocarbon or hydrocarbons such as ethane, propane, butane or mixtures of the same, may be stored in the tank, shown in the drawing. These hydrocarbons have vapor pressures of not less than 25 lbs. per square inch, and not greater than 500 lbs. per square inch at ordinary temperatures. From this tank, the gas may be fed by way of a conduit 2, through a regulating or expansion valve 3, and into a pipe 4. Of course, a fuel such as substantially pure butane, a liquid, if permitted to expand or vaporize, will decrease in temperature, so in its cooled condition, the fuel is fed by the line 4, into a heat exchanger 5, where it travels around the tubes 6, and finally exits through a valved conduit 7, which introduces the same into a vaporizer 8 of the tubular type. This vaporizer is heated by any suitable agent, such as steam, hot water, etc., which enters through the pipe 9, and is discharged through the pipe 10. The fuel vaporized in the part 8, travels through a conduit 11, having a suitable regulating valve 12, and is discharged into a proportioning or mixing mechanism 13, where it is mixed in proper proportions with air or the like, and the air-gas mixture is discharged by way of a pipe 14, which leads the same to storage or to a pipe line.

Valves 20 in the conduits 2, 4 and 7, permit the feeding of the light hydrocarbon material directly to the vaporizer 8 when desired, without passing the same through the heat exchanger 5.

The air or other suitable gas employed in the system enters the heat exchanger 5 at the point 15, and it, of course, may be forced in under pressure. This air travels through the tubes 6 in heat exchange relation with the fuel gas, and consequently, the temperature of the air is lowered so that substantially all the moisture is condensed out and may be discharged by way of the line 16. By controlling the expansion valve 3, greater or less expansion of the fuel gas may take place, in order that the temperature of the heat exchanger may be regulated. Furthermore, the air is not alone dehydrated in the heat exchanger 5, but it imparts its heat to the fuel gas, so that the latter is partially vaporized before entering the vaporizer 8, in which it is completely vaporized.

A conduit 17 connects the heat exchanger 5 to the proportioning mechanism 13, and functions to feed the dehydrated air from the heat exchanger to the mechanism 13.

It is advisable in a system of this character to pipe the air from the exterior of the building in which the machinery is housed. This adds somewhat to the safety of the plant, particularly in case any butane vapors or the like escape in the mixing machine room, and are drawn into the air intake, and it is also of some virtue when it is desired to partially dehydrate the incoming air by means of chilling the same in the heat exchanger with the boiling butane or the like, from which vapor for the system is evolved.

In operating the system, the light hydrocarbon or hydrocarbons is first expanded into the air cooler or heat exchanger 5, and the air taken in to the mixing machine 13 passes through the cooler prior to entering the mixing machine. Due to the particular temperature level involved, only a small part of the latent heat of vaporization will be transferred to the incoming air, and as a consequence, a mixture of hydrocarbon liquid and vapor will pass from the heat exchanger 5, into the second or main vaporizer 8, in which the remainder of the latent heat of vaporization will be supplied by steam, hot water, etc.

The pressure regulator 3 on the liquid line 2, can be so adjusted that the temperature level in the air cooler will be such that the air passing to the mixing machine 13, will be at 33° or 34° F. This means that any moisture condensed from the air can be drawn off from the lower end of the heat exchanger through the pipe 16, in a liquid condition, whereas if the temperature is held below the freezing point of water, such condensate would freeze on the tubes, and eventually stop up the apparatus entirely. It is probably best that this preliminary vaporizer 5 should be laid horizontally with the air passing through the tubes 6, and the boiling hydrocarbon or hydrocarbons surrounding and submerging all of the tubes and occupying

the shell space. A counter-current flow between the air and the fuel gas can be arranged. However, this would be of no great advantage, as all of the tube surface would be subjected to about the same temperature. As stated above, the mixed liquid and vapor would pass then into the bottom of the vertical vaporizer 8, and the process would continue in the normal manner.

From calculations on this situation, we find that such pre-cooling of the air would not be so advantageous during cold weather or in the winter time, but, on the other hand, in the summer, particularly when atmospheric temperatures of 90° F. or above were prevalent and when the relative humidity might be high as would be the case during or just after a summer shower, a very considerable amount of water would be condensed.

Some of our preliminary calculations are shown below for illustration.

1 M cu. ft. 540 B. t. u. butane-air mixture has 169 cu. ft. butane vapor of 1.95 Sp. Gr. 1.95 Sp. Gr. $\times$.077 lbs. per cu. ft. (air) $\times$ 169 cu. ft. = 25.3 lbs. butane vapor per M cu. ft.

831 cu. ft. of air per M finished gas $\times$.047 lbs. per cu. ft. at 60° F. = 39 lbs. air per M cu. ft. $\times$.237 specific heat of air = 9.23 B. t. u. per °F. change in air temperature.

25.3 lbs. butane per M $\times$ 170 B. t. u. per lb. latent heat of vaporization = 4301 B. t. u. refrigeration per M cu. ft. finished gas. 9.23 B. t. u. per °F. dropped in air temperature = 467° F. possible decrease in air temperature.

It is known that this decrease is impossible due to the temperature level at which the butane will take on this latent heat of vaporization, however, it is very easy to reduce the air temperature to 33 or 35° F. with only a small amount of exchange surface. The value of K should be fairly high due to the boiling liquid on one side of the tubes, although the low velocity air stream on the other side will tend to hold this value down.

Assuming a regular summer time condition with the intake air at 90° F. and a relative humidity of 70%, we note that the vapor volume content of water in air is .047 at 90° F. which, when multiplied by .70 relative humidity, equals .0329 parts H₂O in the air under these conditions. If this air is cooled to 40° F., the water-vapor content will be .0082 parts by vapor volume, therefore, under practically any summer time condition, this dehydration will be very effective and even necessary to prevent condensation in the pipe line.

The dew point of the water vapor in the air will be still further decreased by the admixture of the 16.9% of butane vapor. In one example, which we worked out where the air had been cooled to 40° F. and had a

water-vapor content of .00823 parts by vapor volume, the final results after mixing with sufficient butane to produce a 540 B. t. u. gas (which took .831 parts of air and .169 parts of butane vapor), the final composition of the finished gas was .00683 parts H_2O , .82417 parts air, .16900 parts butane, 1.00000 total at 14.7 pounds absolute times .00683 parts H_2O , we find the absolute pressure effective on the water vapor to be .1004 pounds and checking back, we note that the dew point of the water vapor has been lowered to 35° F. or 5° due to the butane percentage therein.

The terms and expressions employed herein are used as terms of description and not of limitation, and there is no intention in the use of such terms, and expressions, of excluding any equivalents of the features shown or described, or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed.

What we claim and desire to secure by Letters Patent is:

1. In a method of the character described, vaporizing a liquefied normally gaseous hydrocarbon material to absorb heat, passing air containing moisture in heat exchange relation with said material while the latter is undergoing vaporization for the purpose of condensing the moisture out of the air, and subsequently mixing the dehydrated air and vaporized hydrocarbon material to produce a combustible mixture.

2. In a method of the character described, vaporizing a liquefied normally gaseous hydrocarbon fluid, passing moist air in heat exchange relation with the fluid while the latter is undergoing vaporization, subsequently heating said fluid to completely vaporize the same, and then mixing the vaporized fluid with the dehydrated air.

3. In a method of the character described, storing a normally gaseous hydrocarbon fluid in liquefied condition, feeding the liquefied fluid from storage while permitting the same to vaporize, passing the fluid while it is undergoing vaporization in heat exchange relation to moist air, and thereby condensing moisture out of the air and heating the fluid, and subsequently mixing the dehydrated air with the vaporized fluid to produce a combustible mixture.

4. In a method of the character described, vaporizing a normally gaseous hydrocarbon fluid from liquid to gaseous state, utilizing the reduced temperature thus created to condense moisture out of air, and then mixing the dehydrated air with the vaporized fluid.

5. In a method of the character described, vaporizing a normally gaseous hydrocarbon fluid from liquid to gaseous state, utilizing the reduced temperature thus created to condense moisture out of air, and then mixing

the dehydrated air with the vaporized fluid, the fluid forming not more than 25% of said mixture.

6. In a method of the character described, vaporizing a liquefied normally gaseous hydrocarbon material having a vapor pressure of not less than 25 lbs. per square inch and not greater than 500 lbs. per square inch at ordinary temperatures, passing moist air in heat exchange relation with said material while the latter is undergoing vaporization for the purpose of condensing the moisture out of the air and heating said gaseous hydrocarbon material, and subsequently mixing the dehydrated air and vaporized hydrocarbon material to produce a combustible mixture.

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