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EXPANSION REFRIGERATION SYSTEM AND METHOD

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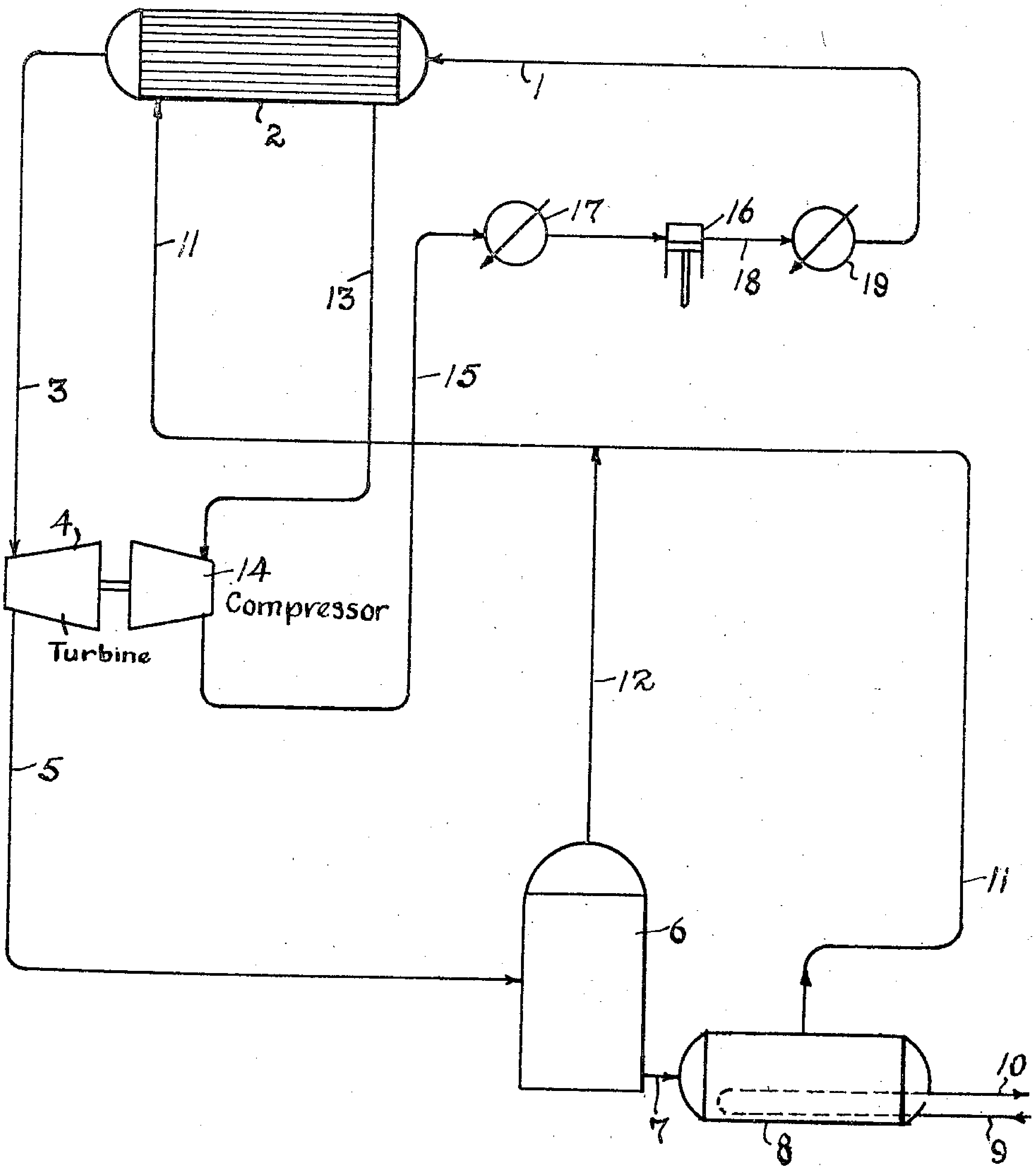

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EXPANSION REFRIGERATION SYSTEM AND METHOD

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13 Claims. (Cl. 62—115)

This invention is for a refrigerating system and method by which refrigeration is produced by isentropically expanding the refrigerant to bring about the liquefication of a considerable portion thereof.

The broad object of this invention is to provide a method and apparatus by means of which the isentropic (reversible adiabatic) expansion of the refrigerant is employed.

A more specific object of the invention is to employ this principle with hydrocarbon refrigerants, and particularly one-component refrigerants such as propane, methane, or the like.

Another object of the invention is to provide a refrigeration process employing a relatively pure hydrocarbon refrigerant vapor by expansion under conditions to effect liquefication of a considerable portion thereof and the use of the liquefied portion as the refrigerant.

A still further object of the invention is to provide an apparatus and method operating in a closed refrigeration cycle wherein the refrigerant such as methane is compressed, cooled with previously expanded methane vapors, expanded isentropically to a very low temperature to produce a substantial quantity of liquid methane. The resulting liquid is then separated from the vapor to be utilized in the refrigeration effect and the separated vapors are utilized in the previously mentioned step to cool the compressed methane prior to its expansion and the vapors are then compressed to be used over again.

Other and more detailed objects of the invention will be apparent from the following description of the embodiment thereof illustrated in the accompanying drawings.

This invention resides substantially in the combination, construction, arrangement and relative location of parts, steps and series of steps, all as will be described in detail below.

In the accompanying drawing, the single figure is a diagrammatic and schematic illustration of an apparatus in accordance with this invention.

The compressed hydrocarbon vapors are delivered through the line 1 to the heat exchanger 2 and from there through the line 3 to an expander such as an expansion turbine 4. From this turbine the expanded vapors including an appreciable percentage of liquefied hydrocarbon (condensate) is delivered by the line 5 to the scrubber 6 where the vapor and liquid phases are separated. The liquid phase comprising the further cooled liquefied hydrocarbon is passed by the line 7 to a flooded type evaporator 8 comprising the desired refrigeration effect. The fluid to be cooled

is delivered to the evaporator 8 through the line 9 and removed therefrom through the line 10. The vapors resulting from the evaporation of the liquid in the evaporator 8 are returned, from the vapor space of the evaporator 8, through the line 11 to the heat exchanger 2. The vapors separated in the scrubber 6 are also delivered by line 12 to the heat exchanger 2 through the line 11. The vapors in the heat exchanger 2 are passed by the line 13 to the first stage compressor 14 driven by the turbine 4. Compressed vapors pass by the line 15 to the second stage compressor 16 after passing through the water cooled cooler 17. The compressed vapors from the compressor 16 are delivered by the line 18 to a water cooled cooler 19 and from there pass into the line 1.

The heat exchanger 2 can be of any suitable and well known type available in the art and may, for example, consist of a casing forming one chamber and a plurality of tubes forming the second chamber. The compressed vapors from line 1 pass through the tubes to line 3. The vapors delivered by line 11 to heat exchanger 2 fill the chamber surrounding the tubes thereof. The heat exchanger 8 is a flooded type evaporator wherein the liquid refrigerant to be evaporated is admitted to the shell in such a manner as to submerge the tube bundle through which the material to be refrigerated or cooled is flowing. As is well understood and as is diagrammatically illustrated in the drawing, the tube bundle in such an evaporator is usually positioned so as to be eccentric to the shell axis, thus allowing a certain amount of free vapor space above the tube bundle and thus above the level of liquid refrigerant which submerges the bundle. Thus, the vapors delivered by line 11 to heat exchanger 2 are withdrawn from the free vapor space of the evaporator 8.

The scrubber 6 may be any device suitable to the purpose of separating the two phase refrigerant into its component vapor and liquid content. There are many devices suitable for this purpose known to the art.

The turbine 4 may be any suitable and available type of centrifugal or reciprocating expander of which the Kapitza turbine is an example of the former. The expander must be of the type capable of handling fluids containing an appreciable liquid content. Suitable forms of Kapitza turbines are disclosed in U. S. Patent No. 2,280,585, granted April 21, 1942.

The compressed refrigerant delivered by line 3 to the expander 4 is in its vapor or partially liquefied state at a given pressure and at or close to the corresponding saturation temperature. In order to insure the presence of a substantial amount of condensate in the exhaust from the expander 4, the expander must perform work. Thus, although the compressor 14 may be driven by some other means it is preferable to drive it by the expander 4 in order that the total heat content of the vapor stream 3 be lowered by an amount sufficient to produce an appreciable amount of condensate in the exhaust of the expander. Those skilled in the art will understand that by this operation the operation of the expander is in accordance with the second law of thermodynamics. By this method of operating considerably more heat energy is available because of the release of latent heat resulting from the relatively large percentage of condensate formed by what may be termed isentropic expansion.

This two phase stream is then divided into its vapor and liquid phases in the scrubber 6 and the liquid portion thereof is expanded in the heat exchanger 8 so as to cool the material reaching it through the line 9 so that on leaving it through the line 10 it will be at the desired low temperature. The resulting refrigerant vapors passing through the lines 11 and 12 still quite cool are passed in heat exchange relation with the compressed refrigerant vapors reaching the heat exchanger 2 through the line 1, so as to chill them at the operating pressure used, to or close to their dew point. The relatively warm vapors are then passed by line 13 to compressor 14 where they are compressed to initial higher pressure, precooled in the cooler 17, further compressed to a final higher pressure in the compressor 18 and precooled in cooler 19 for delivery to the heat exchanger 2.

It will be seen that a system of this type eliminates stepwise or cascade refrigeration cycles commonly used today. It will also be apparent that this system and method may be used for the self condensation of any one gas or vapor stream.

A set of suitable operating conditions may be helpful in fully understanding the invention. It will be assumed that methane is to be used as the refrigerant. Methane is delivered at a pressure of 200 pounds per square inch at a temperature of 95° F. by line 1 to the heat exchanger 2 from which it issues at the same pressure but at a temperature of —175° F., which are conditions for substantial saturation. This stream is then expanded in the turbine 4 and the exhaust is at a pressure of about 20 pounds per square inch and a temperature of —230° F. The exhaust stream contains about 24% of liquid methane. The exhaust stream is then separated into its vapor and liquid phases in the scrubber 6 and the liquid at the same pressure and temperature is delivered to the heat exchanger 8 where evaporation occurs. The resulting vapor at a pressure of 20 pounds per square inch and a temperature of —230° F. joins the vapor at the same pressure and temperature coming from the scrubber 6 through the line 12 and the whole is delivered to the heat exchanger 2. Of course, the material to be refrigerated is cooled by heat exchange through the walls of the tubes of the heat exchanger 8. The vapors delivered through the line 11 are at saturation temperature and are used to sub-cool the precooled stream delivered by line 1 into the heat exchanger 2 from a temperature of 95° F. to a temperature of —175° F. as previously stated. These vapors are then delivered by line 13 at a pressure of 20 pounds per square inch and a temperature of 90° F. to the compressor 14 from which they issue at a pressure of 40 pounds per square inch and a temperature of 185° F. They are delivered to and issue from the cooler 17 at the same pressure at a temperature of 95° F. The compressor 16 raises their pressure to 200 pounds per square inch and a temperature of 325° F. The compressed stream is then cooled in the cooler 19 to a temperature of 95° F. By calculation it will be found that the overall thermal efficiency of the system under these conditions is about 28%.

Although the system is illustrated as driving the compressor 14 from the turbine 4, it will be understood that compressor 14 can be driven from some other power source. However, in the system as disclosed the centrifugal expander is employed to drive the centrifugal compressor in order to take advantage of the energy produced by the isentropic expansion of the saturated vapor stream in the turbine 4.

From the above description it will be apparent that the apparatus and method herein disclosed employs certain novel features of assembly and operation whereby a saturated or sub-cooled and even possibly partially condensed vapor is isentropically expanded to produce a substantial amount of liquid and the condensate so produced is utilized by revaporization as the refrigerant.

It will be understood by those skilled in the art that this apparatus and method may be varied without departure from these principles, and I do not, therefore, desire to be limited in the scope of protection except as required by the claims granted me.

What is claimed is:

1. A method of refrigeration comprising compressing a gas to superatmospheric pressure, cooling the gas to about saturation temperature at that pressure, isentropically expanding said gas to liquefy a portion thereof, separating the liquid portion from the unliquefied gas, and passing the liquid portion in heat exchange relation with a warmer substance to be cooled.

2. In the method of claim 1, the step of evaporating the liquid portion while in heat exchange relation with the substance to be cooled.

3. In the method of claim 1, said gas comprising a single gas such as methane.

4. In the method of claim 1, the additional steps of evaporating the liquid portion during heat exchange with said substance, returning the gas formed by evaporation in heat exchange relation with said gas at superatmospheric pressure to effect said cooling thereof to saturation temperature.

5. In the method of claim 1, the additional steps of evaporating the liquid portion during heat exchange with said substance, returning the gas formed by evaporation in heat exchange relation with said gas at superatmospheric pressure to effect said cooling thereof to saturation, and compressing and cooling said gas, formed by evaporation in several stages to provide said superatmospheric gas at saturation temperature.

6. In the combination of claim 1, evaporating said liquid portion while in heat exchange relation with said substance, compressing the gas formed by said expansion step and said evaporation step, by the energy generated in said expansion step.

7. A refrigeration method comprising isentropically expanding a saturated stream of compressed

gas to liquefy a portion thereof, separating the liquid portion from the unliquefied portion, evaporating the liquid portion in heat exchange relation with a substance to be cooled, and returning the gas formed from said separation and evaporation steps in heat exchange relation with compressed gas to cool it to saturation temperature, said saturated gas supplying the gas for isentropic expansion.

8. In an apparatus of the type described, the combination comprising a source of compressed and saturated gas, an expander for liquefying a portion of said gas, means for separating the liquid portion from the unliquefied portion, and means for evaporating the liquefied portion in heat exchange relation with a substance to be cooled.

9. In the combination of claim 8, means for passing the gas from said separating and evaporating means in heat exchange relation with compressed gas to cool it to saturation temperature.

10. In the combination of claim 8, means for passing the gas from said separating and evaporating means in heat exchange relation with compressed gas to cool it to saturation temperature, and means driven by said centrifugal expander for compressing the gas after passing through said heat exchange means.

11. In the combination of claim 8, means for passing the gas from said separating and evaporating means in heat exchange relation with compressed gas to cool it to saturation temperature, means driven by said centrifugal expander for compressing the gas after passing through said heat exchange means and means for delivering the compressed gas to said heat exchange means.

12. In the combination of claim 8, means for passing the gas from said separating and evaporating means in heat exchange relation with compressed gas to cool it to saturation temperature, means driven by said centrifugal expander for compressing the gas after passing through said heat exchange means, and means including cooling means for delivering the compressed gas to said heat exchange means

13. In the combination of claim 8, said expander being a centrifugal expander.

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