

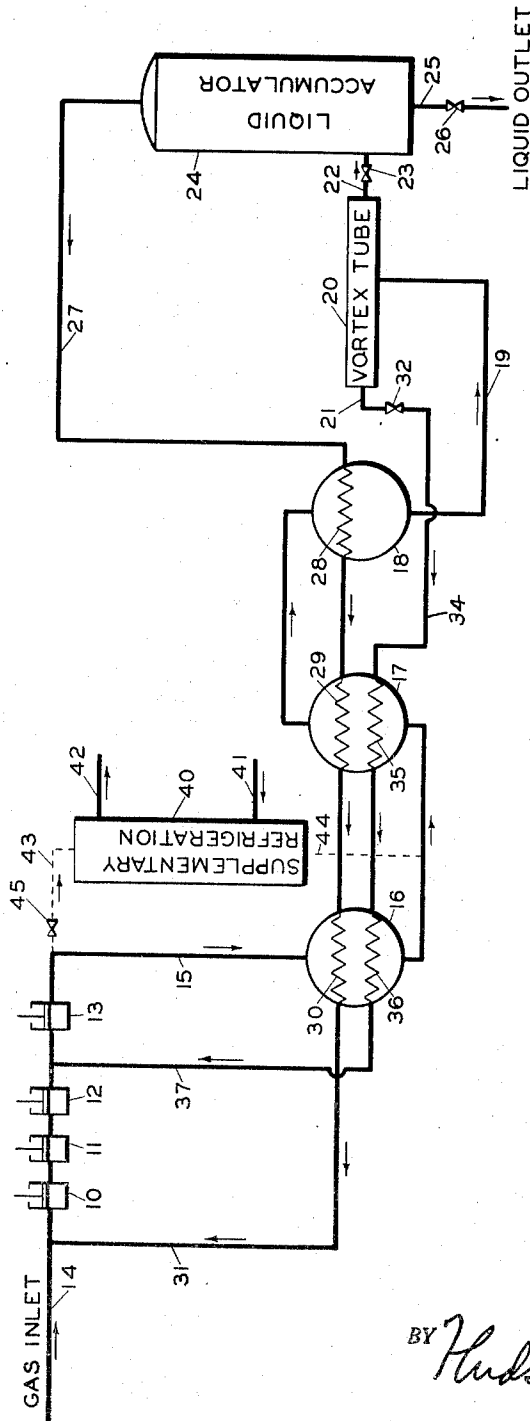
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METHOD OF AND APPARATUS FOR LIQUEFYING GASES

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METHOD OF AND APPARATUS FOR
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This invention relates to a method of and apparatus for liquefying gases.

Heretofore, the liquefaction of gases having an extremely low melting point has been accomplished by compressing the gases to be liquefied, and passing the compressed gases through an expansion valve where some of the gases are liquefied due to the Joule-Thomson effect. In this process, all of the gases are passed through the expansion valve and the gases leave the expansion chamber at atmospheric pressure. Accordingly, a considerable amount of power is required for driving the compressor to force the entire volume of gas through the expansion chamber.

It is an object of this invention to provide a method of and apparatus for the liquefaction of gases without passing the entire stream through an expansion valve.

It is a further object of the invention to provide a method and apparatus wherein about one-half the stream is returned to the compressor at a high pressure without passing through the expansion valve.

It is a still further object of the invention to provide gas liquefaction apparatus which is simple in construction, reliable in operation, and which contains a minimum of moving parts.

Various other objects, advantages and features of the invention will become apparent from the following detailed description taken in conjunction with the accompanying drawing, in which:

The figure is a schematic flow diagram of my novel gas liquefaction apparatus.

Referring now to the drawing in detail, the gas liquefaction apparatus includes a multi-stage compressor, the successive stages of which are indicated by reference characters 10, 11, 12, and 13. The gas to be liquefied is fed through a conduit 14 to the low pressure stage 10 and this gas emerges at high pressure from stage 13 from which it passes through a conduit 15 to a multi-stage heat exchanger comprising units 16, 17 and 18. In the heat exchanger, the compressed gases are progressively cooled to lower and lower temperatures and the cooled compressed gases then pass through a line 19 into a vortex tube 20.

The vortex tube 20 is similar to that shown in U. S. Patent 1,952,281 to G. J. Ranque and its function is to separate the incoming gas into a high temperature stream which emerges through a conduit 21 and a low temperature stream which passes through a conduit 22, the pressure being reduced by about 50 per cent as

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the gas passes through the tube. As set forth in the aforementioned patent, the vortex tube may include a chamber having the shape of a surface of revolution, such as a cylinder, this chamber having an inlet pipe for introducing the gas to be treated tangentially into a central region of the chamber. A gyratory motion is imparted to the fluid as it enters the chamber, and means are provided to divide the gas into two concentric sheets moving along each other so that the outer sheet is compressed by the inner sheet and by the action of centrifugal force. The work thus produced causes a substantial rise in temperature in the outer sheet and a corresponding drop in the temperature of the inner sheet.

From the vortex tube 20, the stream of low temperature gas passes through conduit 22 and an expansion valve 23 into a liquid accumulator tank 24. The sudden drop in pressure produced by expansion valve 23 causes a portion of the gas stream to be liquefied, due to the Joule-Thomson effect. The resulting liquid accumulates in tank 24, and may be removed through a conduit 25 which is controlled by a valve 26. The uncondensed gases from the chamber 24 pass through a line 27 through coils 28, 29 and 30 in the respective stages of the heat exchanger unit whereby heat exchange occurs between the relatively cold uncondensed gases passing through line 27 and the compressed relatively hot gases passing through conduit 15 from the high pressure compressor stage 13. After passing through the heat exchange coils, the uncondensed gases flow through a conduit 31 for recycling to the first or low pressure stage 10 of the compressor.

The high temperature stream passes through conduit 21 and is controlled by a valve 32 which regulates the proportion of gas passing through the respective conduits 21, 22 and which thereby controls the respective temperatures of the high temperature stream and low temperature stream. From the valve 32, the high temperature stream passes through a conduit 34, to a coil 35 in heat exchanger stage 17, a coil 36 in heat exchanger stage 16, and a conduit 37 from which it is recycled to the high pressure stage 13 of the compressor.

It is a feature of the invention that the high temperature stream from the vortex tube is at a sufficiently high pressure that it may be recycled to the high pressure stage 13 of the compressor rather than to the low pressure stage 10. This produces a substantial power saving

and thereby reduces the cost of operating the compressor unit. This economy cannot be realized where the entire output of the compressor is passed through the expansion valve.

In some cases, it may be advantageous to provide a supplementary refrigeration unit 40 which is provided with inlet 41 and an outlet 42 for refrigerating fluid. This unit may advantageously be provided with conduits 43 and 44 which communicate, respectively, with the output conduit 15 of the compressor and the conduit connecting heat exchange stages 16 and 17, a valve 45 being provided to regulate the proportion of gases flowing through the supplementary refrigeration unit. This substantially increases the output of the system without a proportionate increase in the cost of operation. It will be noted that the only moving parts required in the system are located in the compressor unit and no moving parts are exposed to extremely low temperatures. This provides increased simplicity and reliability of operation for the liquefaction apparatus.

While the invention has been described in connection with a present, preferred embodiment thereof, it is to be understood that this description is illustrative only and is not intended to limit the invention, the scope of which is defined by the appended claims.

Having described this invention, I claim:

1. Apparatus for liquefying gases comprising, in combination, a gas compressor unit having a low pressure stage and a high pressure stage, a vortex tube for dividing high pressure gas from said compressor into a high temperature stream and a low temperature stream, means for liquefying a portion of the gas in said low temperature stream, and means for recycling said high temperature stream to the high pressure stage of said compressor.

2. Apparatus for liquefying gases comprising, in combination, a gas compressor unit having a low pressure stage and a high pressure stage, a vortex tube for dividing high pressure gas from said compressor into a high temperature stream and a low temperature stream, means for liquefying a portion of the gas in said low temperature stream, means for recycling said high temperature stream to the high pressure stage of said compressor, and means for effecting heat exchange between the high pressure gas from said compressor, the high temperature gas from said vortex tube, and the uncondensed gases from said liquefying means.

3. Apparatus for liquefying gases comprising, in combination, a multi-stage gas compressor unit, a multi-stage heat exchanger for cooling compressed gases from said unit, a vortex tube for dividing the cooled compressed gases into a stream of relatively high temperature gases and a stream of relatively low temperature gases, an expansion valve for condensing a portion of said stream of low temperature gases, means for conveying the uncondensed gases through each stage of said heat exchanger to the first stage of said compressor, and means for conveying said stream of high temperature gases through the first stages of said heat exchanger to a high pressure stage of said compressor.

4. Apparatus for liquefying gases comprising, in combination, a multi-stage gas compressor

unit, a multi-stage heat exchanger, means for feeding a portion of the compressed gases from said unit to the first stage of said heat exchanger, a supplementary cooling unit, means for feeding the rest of said compressed gases through said supplementary cooling unit to a subsequent stage of said heat exchanger, a vortex tube for dividing the cooled compressed gases from the last stage of said heat exchanger into a stream of relatively high temperature gases and a stream of relatively low temperature gases, an expansion valve for condensing a portion of said stream of low temperature gases, means for conveying the uncondensed gases through each stage of said heat exchanger to the first stage of said compressor, and means for conveying said stream of high temperature gases through the first stages of said heat exchanger to a high pressure stage of said compressor.

5. Apparatus for liquefying gases comprising, in combination, a multi-stage gas compressor unit, a multi-stage heat exchanger, means for feeding a portion of the compressed gases from said unit to the first stage of said heat exchanger, a supplementary cooling unit, means for feeding the rest of said compressed gases through said supplementary cooling unit to a subsequent stage of said heat exchanger, a vortex tube for dividing the cooled compressed gases from said heat exchanger into a stream of relatively high temperature gases and a stream of relatively low temperature gases, a valve controlling the high temperature stream thereby to regulate the relative proportions of gases in said streams, an expansion valve for condensing a portion of said stream of low temperature gases, means for conveying the uncondensed gases through each stage of said heat exchanger to the first stage of said compressor, and means for conveying said stream of high temperature gases through the first stages of said heat exchanger to a high pressure stage of said compressor.

6. In the art of liquefying gases, the steps which consist in compressing the gas to be liquefied, causing the compressed gases to flow with a gyratory helical motion along a surface of revolution, dividing said gas into two coaxial sheets moving along each other, thereby to provide an outer stream of high temperature gas and an inner stream of low temperature gas, rapidly expanding said low temperature stream to liquefy a portion of the gases including therein, effecting heat exchange between said high temperature stream, the uncondensed gases in the low temperature stream, and said compressed gases, and recycling the high temperature stream and the uncondensed portion of the low temperature stream.

7. The process of claim 6 wherein the high temperature stream is recycled to a high pressure region of the compression zone.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,901,389	Hazard-Flamand	Mar. 14, 1933
1,952,281	Ranque	Mar. 27, 1934