FIG. 2A
METHOD AND APPARATUS FOR LIQUEFACTION OF NEON

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5 Claims

ABSTRACT OF THE DISCLOSURE

Method of compressing large volumes of neon for liquefaction of large volumes for industrial use and preliminarily cooling the compressed neon and expanding a portion of the cooled compressed neon in a throttling process expansion and a series work expansion thereby further cooling it. The expanded neon is used to cool the remainder of compressed neon which is subsequently throttled or expanded to liquify it.

Apparatus compressing neon and cooling it comprising means to divide the compressed neon main flow and expand a part thereof in a turboexpander and using the expanded cooled neon to cool compressed unexpanded neon, in a heat exchanger group, which is then throttled and liquefied by a main throttle. The neon itself thus provides the principal cooling agent.

The present invention relates to a method and apparatus for liquefying a gas and more particularly for liquefaction of neon.

There are two principal known methods for liquefying gas neon. A first method is a cycle based on simply throttling the gas after preliminary cooling with liquid nitrogen. The final efficiency of this cycle is quite low. In order to obtain an acceptable coefficient of liquefaction (0.15–0.18) it is necessary to subject the neon to a very high compression pressure, for example 100 to 220 atmospheres, which results in the consumption of a very large amount of energy and the need of heavy and expensive apparatus. A second known method for liquefaction of neon is based on condensation of neon conveyed through a bath of liquid hydrogen. The method is very simple and effective but the system for liquefying the neon depends on a system for liquefying hydrogen which is very expensive and dangerous. The liquefaction of one liter of neon in this system requires the evaporation of about four liters of hydrogen. Thus this second method is practical for production of large quantities or volumes of liquid neon only in the vicinity of very large sources of liquid hydrogen.

It is a principal object of the present invention to provide a new and improved, simple and inexpensive apparatus and method of liquefaction of neon with a minimum expenditure of energy input.

According to the method of the invention the shortcomings of the described methods are overcome. The method makes use of an isentropic expansion of a part of the neon flow after preliminary cooling thereof with liquid nitrogen and the expanded cooled neon cools the unexpanded neon which is then liquefied by throttling. This method allows reduction of the compression pressure applied to neon to about 30 atmospheres. The energy consumption, proportional to the ratio of the pressure, is diminished about six times in comparison with the method described, with a cycle of simple throttling. The reduction in work input is very important in industrial production of liquid neon. Moreover, the method according to the invention eliminates the use of liquid hydrogen which is both very expensive and dangerous to handle. A feature of the method for liquefaction of neon according to the invention makes use of a combined cycle consisting of preliminary cooling, by means of nitrogen throttling and expansion of a part of the compressed neon in a turboexpander and using the expanded neon for cooling compressed neon which is throttled after cooling to liquefy it. The main source of cooling is the neon itself since the expanded neon is directed in a counter-flow heat exchanger arrangement to cool unexpanded compressed neon of the main flow.

The use of a turboexpander for liquefaction of neon is quite advantageous and particularly more advantageous than using hydrogen or helium as a cooling agent since the velocity of the sound is small which makes it possible to realize the cycle with isentropic expansion of the gas without the shortcomings inherent in other expansion apparatus, for example an expansion apparatus.

Other features and advantages of the method and apparatus in accordance with the present invention will be better understood as described in the following specification and appended claims in conjunction with the following drawings in which:

FIG. 1 is a schematic diagram of apparatus according to the invention and a flow chart of a cycle of the method according to the invention;

FIG. 2 is a diagrammatic vertical section view of apparatus for neon liquefaction provided with the invention;

FIG. 2A is a diagrammatic enlarged vertical view of a part of the apparatus in FIG. 2; and

FIG. 3 is a fragmentary longitudinal section view of a turboexpander of FIG. 2 on an enlarged scale.

The method and cycle of the apparatus for carrying out the invention and the principles thereof are illustrated in FIG. 1. In accordance with the invention neon gas is stored in a storage tank or container 1 from which a compressor 2 takes a suction and compresses the neon to a high pressure, in the order of 30 atmospheres. The gas is then discharged through a line 3 to a heat exchanger 4 where it is cooled by reverse flow neon under low pressure to about 78 degrees K. The high pressure neon is illustrated by solid lines, a continuation of line 3, and reverse flow cooling neon, obtained as later explained is illustrated by a broken line 5. The main flow of neon is subjected to cooling in a heat exchanger 6 immersed in a nitrogen bath 7, vented by a vapor vent 9, and continues to be cooled in a heat exchanger 11 cooled by the reverse-flow neon. After having passed through the heat exchangers illustrated diagrammatically the main stream or flow of compressed neon is divided and a portion thereof is taken through a flow path 13 to a throttle valve 14 where it is throttled or expanded to some intermediate pressure between that pressure at which it is received at the throttle and a pressure when it leaves a turboexpander 16 where the throttled neon is expanded to about one atmosphere. The expansion of the neon at the throttle valve 14 and the turboexpander 16 is an expansion without change of entropy.

The expansion of the neon is without exchange of heat and results in a temperature drop. The cooled, expanded neon is applied downstream of a heat exchanger 17 so that it reverse flows back to the source 3 through the various heat exchangers mentioned heretofore cooling the main flow of compressed neon. A heat exchanger 20 receives that main flow of unexpanded, high-pressure neon and a back flow of neon vapors as later explained cools it. The neon vapors cooling the heat exchanger 20 join the expanded, cooled reverse-flow neon intermediate the heat exchangers 17 and 20. Cooling of the high-pres-
sure neon is now at an optimum level for the extent of throttling that is to take place for liquefaction of the neon.

The main flow of compressed neon is throttled by a main throttle 22 where a part of it is liquefied. The liquid obtained, mixed with saturated vapors, is applied to cooling the coils 23 of a large solenoid immersed in a neon bath 24 in a container or receptacle 26. The mixture of liquefied neon and saturated neon vapors obtained after the throttle valve 22 passes through the coils of the powerful solenoid 23 and take away its heat, and the saturated neon vapors from the receiver 26 are recycled as they cool off the heat exchanger 20 and receive the neon vapours discharge from the turboexchanger and are passed, through heat exchangers 17, 11 and 4 in sequence and being delivered of their cold, are gathered in the source or receiver 1 from which the compressor 2 takes a suction again so that a regenerative cycle as described above is realized.

The entire cycle is maintained in a vacuum insulation and when necessary liquefied neon can be drawn out of the liquefier in Dewar vacuum vessels (not shown).

The turboexchanger 16 has connected thereto a turbo-compressor 32 which takes a suction on a neon gas storage or neon source 33 through a flow path or line 34 and compresses the neon and discharges it through a discharge path 35. The heat exchanger 37 immersed in a nitrogen bath 39 where the neon is cooled and it is then returned to the source 33. Thus the energy delivered by the expansion of the neon is dissipated or taken out in the form of heat in the nitrogen bath 39.

The drawing illustrates in FIG. 2 diagrammatically apparatus for carrying out liquefaction as heretofore described with respect to the diagram and flow chart in FIG. 1. The apparatus comprises a liquefier comprising a vessel 45 covered with a cover 46 from which is suspended, for example by welding, coaxially with the vessel an inner conduit support 47, made of example stainless steel, defining a space between it and the vessel 45. Within this space is disposed a "Hempson" heat exchanger 49 comprising a leader distributor or collector 51 to which is delivered compressed neon through an inlet pipe 53 receiving neon under pressure, for example about 30 atmospheres, from a compressor, not shown, as described with respect to the compressor 2 in the diagrammatic illustration of the invention. The vessel 45 is an insulated vessel and has a highly efficient heat insulation jacket consisting of a jacket 52 evacuated and under a high vacuum, so that any heat exchange is substantially impossible between apparatus within the vessel and the exterior thereof. The vacuum is taken by means not shown.

The compressed neon gas flows through the pipes of heat exchanger 49 and is cooled by the counter flow of low pressure neon in the intertube space. The high pressure neon is discharged to a ring header 55 in communication with a similar ring header or collector 56 disposed circumferentially of the central support 47. The collector 56 is immersed in a main nitrogen bath 58. The nitrogen extends downwardly as a nitrogen screen 50 in communication with the main bath 58. The main bath is supplied with liquefied nitrogen through a line 54 and is contained in a conical space of the liquefier below the heat exchanger 49 and boils at a pressure approximate to atmospheric pressure and cools to 77-78° K. The header 56 discharges into a coil 60 in communication with another header 62 which supplied a "Hempson" heat exchanger 63 in communication with a collector or outlet header 66 delivering high pressure neon to a "Hempson" heat exchanger 70 terminating in a collector or header 71 which delivers high pressure neon to a heat exchanger 73 at the lower part of the vessel.

All of the heat exchangers are cooled by neon in a back or reverse flow through intertube spaces thereof. The coil 66, like the coil 6, is immersed in the nitrogen bath 58. The topmost heat exchanger 49 is mounted above this bath and like the other heat exchangers is cooled by the low pressure neon which passes through the intertube spaces of the various heat exchangers and is discharged through a return conduit 76 for return to the supply source 1 hereof as described. The heat exchanger 49 is insulated by the low pressure neon vapors and wound around the central lines 47 and is cooled by neon vapors, from the nitrogen bath 58 which are discharged to the atmosphere through a vent 75.

A compartment 81 wherein a turboexchanger 90, later herein described, is mounted, is connected to the body of the liquefier 52 by means of a flange 84. The same is connected to the general vacuum of the liquefier by means of a flange 84 and a vacuum connection 82.

The turboexchanger is supplied with high pressure neon by means of a connection 89 which divides the main neon flow by a deviation of a line between collectors 65 and 68. This high pressure neon is throttled through a throttle valve 87 which corresponds to the throttle valve 14, so about ten (10) to fifteen (15) atmospheres gauge and it supplies the turboexchanger 90 after which the neon, expanded to about two (2) atmospheres, is passed through a copper line 93 connected to the bottom of the heat exchanger 70 and incorporates the neon vapors to the overall low pressure which is delivered to the turboexchanger 99 corresponding to the throttle valve 22 of FIG. 1. The throttled and expanded neon is delivered in a liquid state mixed with saturated vapors down a line 10 for cooling of the coil of a powerful solenoid 102 immersed in a nitrogen bath 103 contained in a container 104 which is screened by a nitrogen screen 105 and is connected to the top of the apparatus for the purpose of a nitrogen bath 106 contained in a container 107 wherein liquid nitrogen is fed through a line 109. The nitrogen vapors from the container 107 exit into the outer atmosphere through a line 114. This entire arrangement in conjunction with the lower end of the vessel 45 is disposed internally of an insulating compartment or jacket 110 covered with a vacuum-tight cover 111 and held under vacuum in conjunction with the expansion or throttle valve 84 by the means supplying vacuum to the main vessel jacket and the other compartment 81 supported on the liquefier vessel jacket or housing.

The low pressure neon vapors taken from the top part above the level of the liquid neon in the neon container 103 through a line 116 are passed into the lower end of the central structure of the liquefier and as they pass and cool in sequence heat exchangers 73, 70, 63 they pass through lines 165 into the bottom part of heat exchanger 49 and after they have cooled it they pass through line 76 into the receiver (1). From there they are again taken as a suction by the compressor 2. The possibility is provided to draw out liquid neon through the line 115 which is immersed in the neon bath 103 in case this is necessary.

The turboexchanger 99 is shown in detail in FIG. 3 and comprises a nozzle 120 receiving neon gas under high pressure from the main stream 122, in communication with the supply inlet line 123, where it is delivered into a chamber 122, in communication with the supply inlet line 89, defined jointly by a housing 123 and a nozzle throat piece 124. The neon is then at about a pressure of from ten to fifteen atmospheres. The neon under pressure delivered by the nozzle drives a rotor 126
having a diffuser 127 for carrying out the expansion of the neon without exchange of heat thereby effecting a temperature drop therein as heretofore described. The diffuser 127 discharges to the discharge line 93 with which the throat piece 124 is in communication.

A shaft 129 is driven by the rotor 126 driving an impeller 133 in a turbine casing 134 of a turboexpansor 135 taking a suction from a neon storage or source 136. FIG. 2, compressing the neon and discharging it into a heat exchanger 138 immersed in a nitrogen bath 140 supplied with nitrogen by a line 142. The energy delivered by the expanding neon in the turboexpander 90 is removed as heat by the nitrogen bath 140.

The rotor shaft 129 is mounted in a vertical position to preclude any sag since it operates at high speeds, for example over 100,000 revolutions per minute. The weight of the rotor assembly and the axial reaction forces applied thereto by the expanding neon stream are taken up by a thrust bearing 138. Cooled neon under pressure from the main stream is delivered into a space in the bearing housing through a control passageway 140 connected to a neon manifold 148. The neon is throttled or expanded in the clearances between the bearing and its housing and discharged through an outlet 145 connected to a discharge manifold 144 in communication with the expanded low-pressure neon of the system.

The rotor is mounted on aerostatic bearings 150, 151, receiving high pressure neon through respective control inlets 153, 154. The neon is supplied to respective annular chambers 156, 157 and escapes along the clearance space between the shaft and the housing and is discharged through an outlet 160 in communication with the outlet manifold heretofore described.

The turboexpander assembly is effectively sealed with labyrinth seals 161 at the end of the rotor and a labyrinth 162 about the rotating diffuser 127.

Thus those skilled in the art will understand that the invention provides a highly simplified and compact apparatus and a highly effective and inexpensive method and cycle of operation of the apparatus for inexpensive production of large volumes of industrial liquid neon.

While preferred embodiments of the invention have been shown and described it will be understood that many modifications and changes can be made within the true spirit and scope of the invention.

What we claim and desire to be secured by Letters Patent is:

1. A method of liquefying large volumes of neon comprising, providing neon in a gaseous state to be liquefied, compressing the neon to be liquefied, expanding a portion of the cooled, compressed neon to cool it, cooling

the remainder of the compressed neon with said expanded and cooled neon, and expanding and cooling the remainder of the cooled compressed neon to liquefy at least a part of said remainder of neon and expanding a portion of said cooled, compressed neon comprising throttling said portion of neon and thereafter work expanding the neon immediately before cooling the remainder of the compressed neon with said expanded and cooled neon.

2. Apparatus for liquefying large volumes of neon gas comprising, a source of compressed neon under high pressure, means to cool the compressed neon under high pressure, means to remove a portion of the cooled compressed neon including first means to expand it in a throttle process expansion and a work expansion serially without exchange of heat in at least one of the expansions thereby further cooling the expanded neon, other cooling means additionally cooling said neon under high pressure, means to apply the cooled, expanded neon to said other cooling means to cool said neon under high pressure, and second means to expand the additionally cooled, unexpanded neon under high pressure thereby to liquefy it.

3. Apparatus according to claim 2, in which said first means to expand the high pressure neon comprises a first throttle effecting an expansion to a lower pressure and a turboexpander in series with said first throttle.

4. Apparatus according to claim 2, in which said first means to expand the high pressure neon comprises turbo-expansion means expanding the neon substantially without exchange of heat thereby cooling the neon expanded.

5. Apparatus according to claim 2, in which said first means to expand the high pressure neon comprises a throttle and a turboexpander in series, and said second means to expand high pressure neon comprises a main throttle.

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