A method and apparatus for providing nitrogen is provided.
FIG. 3

FIG. 4
METHOD AND APPARATUS FOR PROVIDING NITROGEN

[0001] The present invention relates to a method and apparatus for providing nitrogen. It is usual to provide a customer with nitrogen by means of a gas generating apparatus, such as a cryogenic air distillation apparatus, as well as a nitrogen store that provides gaseous nitrogen supplying the customer when the cryogenic apparatus is out of service and/or is not able to produce all the required flow.

[0002] According to the invention, the gas generating apparatus is started only when it is more economical to use a gas store (in gaseous or liquid form) for providing a customer.

[0003] As shown in FIG. 1, according to the prior art, a gas generator A, in particular for units present on a customer’s site, is generally coupled to an emergency supply means B of the “bulk” type (liquid with evaporator or gas).

[0004] The generator is always in a condition to provide the customer via lines C, E. When the customer consumes more than the nominal amount (100%), the emergency supply means is started and transfers nitrogen via the lines D, E.

[0005] Similarly, when the generator is out of service, the emergency supply means take over.

[0006] In this mode of operation, the generator is started whatever the customer’s consumption. In customer consumption phases that are low compared with what is nominal for the generator, the energy consumption and therefore the production cost is not optimal.

[0007] Operating in this way according to the prior art is illustrated in FIG. 3. At time 0, the customer consumes 20 Nm³/h of nitrogen, this flow being provided entirely by air distillation in a separating apparatus with a simple liquid injection column. As the customer’s consumption increases, the production of the apparatus increases as a consequence to 40 and then 100 Nm³/h at 10 hours and 20 hours respectively. Now, when the customer’s consumption reaches 150 Nm³/h, the separating apparatus continues to produce its maximum flow rate of 100 Nm³/h, the remainder being provided by vaporization of stored nitrogen to produce a flow rate of 50 Nm³/h.

[0008] When the consumption falls to 80 Nm³/h at 50 hours, the production of nitrogen by vaporization is stopped and the production of nitrogen by the distillation apparatus is reduced to 80 Nm³/h. Then, in order to follow the customer’s consumption, the level of production by the apparatus is reduced to 40 and then 20 Nm³/h.

[0009] According to one object of the invention, a method is provided for supplying nitrogen by means of an apparatus for producing gaseous nitrogen by air separation and by vaporization of liquid nitrogen, wherein:

[0010] a) if the customer’s requirements for gaseous nitrogen are below a first threshold, the customer is provided with nitrogen exclusively by vaporization of liquid nitrogen;

[0011] b) if the customer’s requirements for gaseous nitrogen are greater than a second threshold, the second threshold being greater than the first threshold, the customer is provided with nitrogen at least partially by the apparatus for producing nitrogen.

[0012] According to other objects of the invention:

[0013] if the customer’s requirements for nitrogen exceed a third threshold, greater than the second threshold, the customer is provided partially by the apparatus for producing nitrogen and partially by vaporization of liquid nitrogen;

[0014] if the customer’s requirements are between the second and third threshold, the customer is provided solely by the apparatus for producing nitrogen;

[0015] if the customer’s requirements for gaseous nitrogen are greater than the second threshold, the customer is provided with nitrogen solely by the apparatus for producing nitrogen;

[0016] at least one of the first, second and third thresholds is variable according to the price of electricity and/or the price of liquid nitrogen and/or the quantity of liquid nitrogen in the storage vessel connected to the means of vaporization and/or the rate of change of the quantity of liquid nitrogen in the storage vessel;

[0017] if the customer’s requirements for gaseous nitrogen are greater than the second threshold or greater than the second threshold but below the third threshold, the apparatus for producing nitrogen produces gaseous nitrogen with a substantially constant flow rate and:

a) if the customer’s requirements for gaseous nitrogen are less than the substantially constant flow rate, the excess part of gaseous nitrogen is discharged to atmosphere and the rest of the gaseous nitrogen is conveyed to the customer;

b) if the customer’s requirements for gaseous nitrogen are greater than or equal to the substantially constant flow rate, all the gaseous nitrogen flow is conveyed to the customer;

[0018] the apparatus for producing gaseous nitrogen is a cryogenic air distillation apparatus, and as the case may be liquid nitrogen is conveyed to the apparatus for producing gaseous nitrogen in order to participate in keeping it cold.

[0019] According to another object of the invention, an apparatus for providing gaseous nitrogen is provided comprising an apparatus for producing gaseous nitrogen by separation of air, a liquid nitrogen vaporizer, a storage vessel, means for feeding the vaporizer with liquid nitrogen from the storage vessel, means for conveying gaseous nitrogen from the production apparatus to the customer, means for conveying gaseous nitrogen from the vaporizer to the customer and means for regulating at least one of the flows of gaseous nitrogen conveyed to the customer according to the price of electricity and/or the price of liquid nitrogen and/or of the quantity of liquid nitrogen in the storage vessel and/or the rate of change of the quantity of liquid nitrogen in the storage vessel.

[0020] As the case may be, the apparatus for producing gaseous nitrogen is a cryogenic air distillation apparatus.

[0021] The invention will now be described in greater detail with reference to the figures.

[0022] FIG. 2 is an apparatus for supplying nitrogen according to the invention. FIG. 4 is a graph illustrating the operating mode for this apparatus with the method according to the invention.

[0023] According to this invention, it is proposed to reverse the current philosophy. The customer is basically supplied by the “bulk” emergency supply means. When his requirements exceed a certain value, the generator supplants the “bulk” supply. This value is defined so that the cost of production by the generator becomes more economical than the “bulk” supply. It depends on the cost of energy and the cost of the bulk supply.
Beyond the production capacity of the generator, the “bulk” supply supplements the production by the generator for providing the customer.

Thus, as will be seen in FIG. 4, at time 0, the customer consumes 20 Nm³/h of nitrogen, this flow being provided entirely by vaporizing nitrogen coming from a storage vessel (or as the case may be by the inflow of gaseous nitrogen coming from a network). The customer’s consumption then increases to 40 Nm³/h at 10 hours, nitrogen vaporization stops completely, production by the distillation apparatus commences as a consequence at 40 Nm³/h and reaches 100 Nm³/h after 20 hours. Now, when the customer’s consumption reaches 150 Nm³/h, the separation apparatus continues to produce its maximum flow of 100 Nm³/h, the remainder being provided by vaporization of stored nitrogen to produce a flow rate of 50 Nm³/h.

When the consumption falls to 80 Nm³/h at instant 50 hours, the production of nitrogen by vaporization is stopped and the production of nitrogen by the distillation apparatus is reduced to 80 Nm³/h. Then, in order to follow the customer’s consumption, the production level of the apparatus is reduced to 40 Nm³/h. Beyond this value, air distillation is stopped and in order to provide the basic consumption by the customer at 20 Nm³/h, vaporization of liquid nitrogen is started again.

According to the invention, the air separation apparatus may produce, for values between 40 and 100 Nm³/h, the exact desired consumption according to the invention. As illustrated in FIG. 2, a complete assembly 6 comprises a liquid nitrogen storage vessel 1 and at least one cold box 9 of the cryogenic generator.

The gas generator consists of a simple air separation column inside a cold box 9, producing gaseous nitrogen 11 at the head of the column.

An expansion valve 7 placed on the liquid line 3 reduces the pressure of the liquid intended for the vaporizer 5.

An optional connection for liquid nitrogen 8 to the cold box 9 of the cryogenic generator ensures, at least partially, that the generator is kept cold by liquid injection.

The storage vessel is also connected to the vaporizer 5 by the line 3.

The vaporizer is connected to the customer via a line 18.

Between 0 and 10 hours in FIG. 4, the liquid 3 is withdrawn from the storage vessel 1, is expanded in the expansion valve 7 and then vaporized (and reheated to ambient temperature) in the vaporization system 5. The cold box 9 does not operate.

Between 10 and 30 hours, the gas coming from the cold box 9 is conveyed in the customer network through the line 11. No liquid flow coming from the storage vessel is vaporized in the vaporizer 5.

Between time 30 and 40 hours, the gas is produced at the same time by vaporization of nitrogen from the storage vessel and by distillation, the two flows being mixed downstream from the vaporizer 5, (or as the case may be upstream as described in patent application FR 0752579 filed on Jan. 9, 2007).

Between 40 and 60 hours, gas coming from the cold box 9 is conveyed in the customer network through the line 11. No liquid flow coming from the storage vessel is vaporized in the vaporizer 5.

Between 60 and 70 hours in FIG. 4, the liquid 3 is once again withdrawn from the storage vessel 1, its pressure is reduced in the expansion valve 7, and it is then vaporized (and reheated to ambient temperature) in the vaporization system 5. The cold box 9 does not function.

According to a variant of the invention, the air separation apparatus produces a fixed flow with a nominal pressure of 8.3 barg (8.6 barg max). Running is not at a reduced rate and the air compressor of the distillation apparatus is at a fixed speed.

If the customer does not take all the nitrogen produced by the apparatus, part of the nitrogen is vented to atmosphere via a discharge valve or regulating valve IV. This makes it possible to limit the pressure of the column (network pressure N2) to a limit value (PSH, around 7.9 barg), without having to discharge the compressor.

If the customer has a peak consumption, the surplus flow comes from the storage vessel 1 via a liquid pressure reducer 7 (opening around 7.4 barg) which makes it possible to maintain the pressure in the customer’s network.

Starting up: the customer is provided with liquid.

If the level in the storage vessel LT falls at a rate greater than an equivalent production rate judged to be economical according to the cost of liquid nitrogen and electrical energy (for example 20% of the nominal rate) the generator is started. The parameters of this start-up threshold could be established by the IHM. A sliding mean could be established over one to several hours in order to estimate the mean consumption rate so as to obtain a legible and reliable reading of the fall in level.

If the customer’s consumption falls strongly, the generator will stop if the flow provided to the customer by the generator is less than a flow threshold judged to be uneconomical according to the cost of liquid nitrogen and electrical energy (for example 20% of the nominal rate). The parameters of this stop threshold could be established by the IHM.

The flow discharged to atmosphere is estimated by using the fact that this is a function of the Cv of the valve and of its opening, of the pressure PT, and of the temperature of the gas. The flow actually provided by the generator to the customer is then deduced therefrom by the difference between the nominal production flow from the generator and the flow discharged to atmosphere.

Starting the generator, even in the case of low consumption, may be made necessary when the storage vessel contains only a little liquid (for example 10% of the maximum level) in the storage vessel in order to increase the duration of the customer’s supply (via the generator). The consumption of liquid nitrogen is then limited to liquid injection (if there is any).

1.7. (canceled)

8. A method for providing nitrogen by means of an apparatus for producing gaseous nitrogen by air separation and by vaporization of liquid nitrogen, wherein:

a) providing nitrogen to the customer exclusively by vaporization of liquid nitrogen if the customer’s requirements for gaseous nitrogen are below a first threshold;

b) providing nitrogen to the customer at least partially by the apparatus for producing nitrogen if the customer’s requirements for gaseous nitrogen are greater than a second threshold, the second threshold being greater than the first threshold.

9. The method for providing nitrogen as claimed in claim 8, wherein if the customer’s requirements for nitrogen exceed a third threshold, greater than the second threshold, the cus-
customer is provided partially by the apparatus for producing nitrogen and partially by vaporization of liquid nitrogen.

10. The method as claimed in claim 9, wherein the customer's requirements are between the second and third threshold, and the customer is provided solely by the apparatus for producing nitrogen.

11. The method as claimed in claim 8, wherein if the customer's requirements for gaseous nitrogen are greater than the second threshold, the customer is provided with nitrogen solely by the apparatus for producing nitrogen.

12. The method of claim 9, wherein at least one of the first, second and third thresholds is variable according to the price of electricity and/or the price of liquid nitrogen and/or the quantity of liquid nitrogen in a storage vessel connected to the means of vaporization and/or the rate of change of the quantity of liquid nitrogen in the storage vessel.

13. The method of claim 9, wherein if the customer's requirements for gaseous nitrogen are greater than the second threshold and as the case may be below the third threshold, the apparatus for producing nitrogen produces gaseous nitrogen with a substantially constant flow rate and
   a) if the customer's requirements for gaseous nitrogen are less than the substantially constant flow rate, the excess part of gaseous nitrogen is discharged to atmosphere and the rest of the gaseous nitrogen is conveyed to the customer.
   b) if the customer's requirements for gaseous nitrogen are greater than or equal to the substantially constant flow rate, all the gaseous nitrogen flow is conveyed to the customer.

14. The method of claim 8, wherein the apparatus for producing gaseous nitrogen is a cryogenic air distillation apparatus, and as the case may be liquid nitrogen is conveyed to the apparatus for producing gaseous nitrogen in order to participate in keeping it cold.

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