METHOD OF AND APPARATUS FOR DISPENSING GASES

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Application August 26, 1953, Serial No. 306,488

Claims priority, application Great Britain August 27, 1951

17 Claims. (Cl. 62—1)

The present invention relates to the dispensing of gases, the boiling points of which are below or not substantially above atmospheric temperature, and more particularly to a method whereby a fluctuating demand for such a gas may be met from a continuous and relatively steady supply of such gas.

Such conditions are met with, for example, in air separation plants designed primarily for the production of liquid oxygen but adapted to supply a fraction of the oxygen output as gas for pipe line distribution. A fluctuating demand for oxygen is similarly experienced with small separation plants operating directly to supply oxygen for immediate use, for example, in steel manufacture and for oxygen cutting and welding.

In all such cases, attempts to design separation plants of sufficient flexibility to cope with the varying demand have involved serious difficulties and involve a considerable increase in the capital cost of the plant.

It is an object of the present invention to provide a method of dispensing a gas of the type specified so as to meet a fluctuating demand from a continuous supply of gas at a steady rate, such that sufficient gas is always available to satisfy periods of high demand and no loss of gas occurs during periods of low demand.

According to the present invention, such a method for dispensing a gas of the type specified comprises supplying excess gas, available during periods when the supply of gas exceeds the demand, at a pressure in excess of the demand pressure to a storage medium comprising a mass of the liquefied gas, and evaporating gas from the storage medium under reduced pressure during periods when the demand exceeds the supply of gas.

For the sake of clarity, the invention will be described in more detail as applied to the dispensing of gas from an air separation plant in which there is fluctuating demand for gaseous oxygen, but it is not limited to installations of this type. It may, for example, be applied to air separation plants in which the demand is for nitrogen or to plants for the separation of gas mixtures other than air, such as, for example, coke oven gas, or to any other system in which a fluctuating demand for gas has to be met from a steady supply.

The excess product to be stored is gaseous oxygen, the storage means will comprise a suitable vessel insulated to reduce cold losses, and partially filled with liquid oxygen, the quantity of liquid necessary and hence the size of the vessel being governed by the extent of the fluctuations in demand which are to be anticipated.

The vessel is provided with suitable means, such as a series of charging nozzles immersed in the liquid, by which oxygen at the storage pressure and at condensation temperature may be supplied to the body of the liquid and is also provided with means by which gaseous oxygen evaporating from the surface of the liquid in the vessel may pass to the main delivery line.

In operation, when the demand for oxygen is less than the available output of the plant, the excess oxygen after compression to the storage pressure will pass to the storage liquid and will be condensed therein. The pressure within the storage vessel will tend to rise until the storage pressure is reached. Should, however, the demand exceed the supply of oxygen, the pressure within the storage vessel will fall and oxygen will evaporate from the liquid and pass to the delivery line. It will be apparent that a suitable valve system must be provided to ensure automatic operation of the storage system.

Excess oxygen leaving the separation plant will be in a superheated state and after compression to the required pressure it must be cooled to saturation temperature before contacting the storage liquid. This may conveniently be effected by passage of the oxygen through a regenerator, the regenerator being subsequently recooled by passage through it of oxygen evaporated from the storage vessel medium during a period of increased demand.

Where the oxygen leaves the separation plant in the form of gas, it may be compressed to the storage pressure by any suitable form of compressor. However, in many cases, the oxygen will leave the plant as liquid and in this case the liquid oxygen may be brought to the storage pressure by a suitable liquid pump and subsequently vaporized by any suitable means, such as, for example, by heat exchange with the air feed to the plant, prior to contacting the storage liquid.

Since the storage liquid will be at a temperature considerably below atmospheric temperature, the provision of adequate insulation for the storage vessel to minimize cold losses is essential. For this purpose vacuum insulation has been found to be particularly suitable. Some cold losses from the storage vessel are, however, bound to occur and in cases where the oxygen leaves the gas plant in the form of a liquid and is forced to the storage pressure by a liquid pump, such cold losses may be compensated by directing a part of the liquid oxygen from the liquid pump direct to the storage vessel, provision being made to prevent overfilling of the storage vessel during prolonged periods of low demand. Alternatively, cold losses may be compensated by cooling the storage liquid from external sources by either direct or indirect heat transfer.

The initial supply of liquid oxygen to the storage vessel may conveniently be derived from the initial operation of the gas separation plant. Moreover, the liquid oxygen contained in the storage vessel forms a convenient source of oxygen and cold for use in the rapid recoiling of the separation plant after thawing. This will further aid in ensuring continuity in the supply of oxygen.

This invention will now be more particularly described with reference to the accompanying drawing which shows diagrammatically an exemplary apparatus for carrying out a method of dispensing gaseous oxygen to meet a fluctuating demand from a supply provided by a conventional double-column air-separation plant producing liquid oxygen.

Air, after treatment in a carbon-dioxide-removing device 10, is fed through pipe 11 to compressor 12 where it is compressed. The compressed air leaving the compressor 12 is treated in a moisture-removing device 13, and upon leaving the device 13 through pipe 13' divides, part of it passing through a passage 14 in a main heat exchanger H, where it is cooled by indirect heat exchange with the separation products and thence via pipe 15 through an expansion valve 16 to the lower column 17 of a conventional double column A. The remainder of the air passes through pipe 19 to an expansion engine 20 where it is expanded to the lower column pressure and thence through pipe 21 to rejoin the other part of the air entering the lower column.

In the lower column 17, there accumulates at the base an oxygen-rich fraction which is transferred through pipe 22 and expansion valve 23 to the upper column 24 of the
double column A, and at the upper end of the lower column 17 there accumulates at 18 a nitrogen-rich fraction which is transferred through pipe 23 and expansion valve 26 to the top of the upper column 24.

In the upper column the air is separated into: a nitrogen fraction which leaves the top of the column through pipe 27 and passes to the heat exchanger H and thence to waste, and a liquid oxygen fraction which collects at the base of the upper column.

This liquid oxygen fraction is withdrawn through pipe 28, from which a part of the fraction sufficient to satisfy the average demand for gaseous oxygen is withdrawn through pipe 29 while the remainder passes through a bram pipe 31 and valve 31' therein to storage and use as liquid.

The dispensing means preferably comprises a two stage liquid pump, the first stage 32 of which is fed with liquid from pipe 29 and is adapted to elevate the pressure of the liquid to the demand pressure. From the outlet of this stage a pipe 30 leads to a passage 33 through the heat exchanger H and thence through conduit 34 to the installation using the oxygen.

The second stage 35 of the liquid pump is adapted to further elevate the pressure of the liquid oxygen to the storage pressure which must be higher than the demand pressure. From the outlet of this stage a pipe 36 connects to a passage 37 through heat exchanger H from the warm end of which a conduit 38 connects passage 37 to the conduit 34 which conducts gas to the oxygen using installation. From pipe 38 a branch pipe 39 leads to the upper end of a regenerator 40 of suitable construction, such as a chamber filled with a heat-storage material, from the lower end of which a pipe 41 leads through a non-return valve 42 to a series of discharge nozzles 43 immersed within a storage mass 44 of liquid oxygen partially filling a vessel 45. The excess loss of cold from the liquid oxygen storage mass, the vessel 45 is provided with adequate insulation, preferably of the vacuum insulation type. The regenerator 40 is also insulated. The lower end of regenerator 40 is also connected by pipe 46 with the gas space above the liquid 44 in vessel 45. A non-return valve 47 is also preferably interposed in pipe 46. The storage mass is adapted to be isolated from either the liquid pump 35 or the pipe 34 leading to the user installation by means of valves 48 and 49, respectively, interposed in pipe 36 on either side of the junction with pipe 39.

Valves 48 and 49 are openable respectively in response to the below-normal or above-normal demand for oxygen. For example, valve 48 may be constructed to be openable automatically in response to a small pressure increase in conduit 34 caused by the reduction in demand by the consumer and valve 49 may be constructed to be openable automatically in response to a small pressure decrease in conduit 34 caused by above-normal demand.

In spite of the insulation of vessel 45 some cold losses are bound to occur, and to replace these a branch pipe line 50 controlled by valve 51 is connected directly between pipe 36 and vessel 45, by-passing heat exchanger H, through which liquid oxygen at the storage pressure may be added directly to the storage mass 44. A connection 52 controlled by a stop valve 53 may be provided with pipe 50 to permit addition of liquid oxygen to the external transport device, such as a liquid oxygen transport device, or for use in withdrawing liquid oxygen from the storage mass 44 when desired, for example, if some of the stored liquid is to be used for rapid cooling of the column A after an interruption of operation. Suitable liquid-level gauges and safety devices may also be provided for example, a high-temperature relief valve 54 may be connected to conduit 38 between the valves 48 and 49.

In operation, when the demand for gaseous oxygen equals the output of liquid oxygen from the plant other than that withdrawn as liquid at connection 31, the liquid oxygen, after elevation to the demand pressure in the first stage 32 of the pump, is passed through pipe 39 to the heat exchanger passage 33 wherein it is vaporized by indirect heat exchange with the incoming air, and thence through pipe 34 to the user installation.

In these circumstances, both valves 48 and 49 remain closed.

Should the demand for oxygen fall, not all the liquid oxygen pumped by the first stage 32 of the pump will be needed to satisfy the demand. The excess liquid is passed to the second stage 35 of the pump and is then elevated to the storage pressure. Thence it is passed through pipe 36 to the heat exchanger passage 37 where it is vaporized by heat exchange with the incoming air, and the resulting gas passes through valve 48, which opens automatically, to pipe 39, since valve 49 remains closed. The gas which is in a superheated state is cooled by passage through the heat-storage filling of regenerator 40, which has itself been cooled by passage through the exothermic reactions of the storage mass 44 in a previous cycle as hereinafter described. From the regenerator, the gas passes through pipe 41, check valve 42, and is discharged through nozzles 43 into the storage liquid 44, by which it is absorbed. This absorption will cause the pressure within the vessel 44 to rise until the storage pressure is reached.

If the demand for gas exceeds the supply from the plant, valve 49 will be opened automatically while valve 48 will remain closed. Under these conditions, the pressure within vessel 45 will fall and oxygen will evaporate from the storage mass 44. This vapor is withdrawn through pipe 46 and check valve 47 and passes through regenerator 40, which it cools, and thence passes through pipe 39, valve 49, and pipe 34 to the user installation.

While the invention has been described in connection with a specific embodiment of apparatus, it is intended to cover all the changes and modifications of the process and apparatus disclosed which fall within the spirit and scope of the invention. For example, the gas separation plant A may be of the type that produces the product gas as gas at a low pressure, and in place of pumping the liquid product to the desired pressures before heating it, the gaseous product after heating may be compressed to the desired pressures for storage or for delivery to the consumer.

I claim:

1. A method of dispensing a gas having a boiling point below about 21° C. to a consumer having a fluctuating demand at a demand pressure from a supply source providing the gas at a continuous and relatively steady rate of the improvement which comprises providing a confined storage body of the gas in liquid state; passing the excess gas, available from the supply when the rate of supply exceeds the demand, at a pressure higher than the demand pressure into direct and intimate contact with the storage body liquid; providing for increasing vapor pressure acting on the storage body to effect condensation in and combination with the storage body of said excess gas, the temperature of the stored liquid being correspondingly increased; and, during periods when the demand exceeds the supply rate, supplying the excess demand by passing gas from said storage body to said consumer at reducing vapor pressure for evaporation from the storage liquid and correspondingly reducing the temperature thereof.

2. In a method of dispensing a gas according to claim 1, the step of maintaining a liquid level between liquid and vapor phases of said storage body above a predetermined minimum by adding portions of liquefied gas to said storage body after 41 into the direct oxygen generator for losses therefrom tending to reduce the liquid level thereof below said desired minimum.

3. In a method of dispensing a gas having a boiling point below about 21° C. to a consumer having a fluctuat-
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In a method of dispensing a gas according to claim 5 which includes adding liquefied gas having a composition similar to that of the storage body from an external source to said storage body as required to compensate losses therefrom tending to reduce the level of liquid of the storage body below a desired minimum.

11. Apparatus for dispensing a gas having a boiling point at atmospheric pressure below about 21°F to consumer means having a fluctuating demand from a supply means delivering the gas at a continuous and relatively steady rate, which apparatus comprises means for delivering the gas to said consuming means at a demand pressure; a storage medium comprising an insulated pressure vessel holding a mass of the gas in the liquid state and providing a vapor space above the liquid; means including a conduit opening below the level of the mass of liquid gas and operable when the demand by the consumer means is less than said rate for passing the excess gas at substantially saturation temperature and at increasing pressures higher than said demand pressure into said vessel through said mass of liquid gas so as to effect condensation of such excess gas; and means operable when the demand by the consumer means exceeds said rate for withdrawing gas from said storage medium at reducing pressures and passing it to said consuming means to augment the gas from the supply means.

12. An apparatus according to claim 11 in which said supply means is a plant for the low-temperature separation of a gas mixture producing said gas at said continuous and relatively steady rate.

13. An apparatus according to claim 11 in which said storage medium also includes a heat exchange device having heat storage material constructed and arranged for cooling the excess gas when it passes into the liquid mass and for being cooled by gas drawn from the liquid mass during periods when gas is supplied from the storage medium to the consumer means.

14. An apparatus according to claim 11 which includes means for feeding liquefied gas to said storage medium as required to compensate losses therefrom.

15. An apparatus according to claim 12 in which said plant produces the gas in a liquid state, and which includes liquid pumping means and vaporizing and superheating means operable to pump and heat the product to the demand pressure and temperature, and operable to pump the product to the storage pressure and heat it to the demand temperature when the product in excess of demand is to be passed to the storage medium.

16. An apparatus according to claim 12 in which said plant produces the gas in a liquid state, and which includes liquid pumping means and vaporizing and superheating means operable to pump and heat the product to the demand pressure and temperature, and operable to pump the product to the storage pressure and heat it to the demand temperature when the product in excess of demand is to be passed to the storage medium.

17. Apparatus for dispensing a gas having a boiling point at atmospheric pressure below about 21°F to consumer means having a fluctuating demand from a plant for the low-temperature separation of a gas mixture producing said gas at a continuous and relatively steady rate, which apparatus comprises means for delivering said product at a demand pressure to said consuming means; a storage system comprising an insulated pressure vessel holding a body of the gas in the liquid state, a heat exchange device having heat storage
material constructed and arranged for cooling gas product by heat exchange with heat storage material and cooling said heat storage material by heat exchange with vapors of said body; valve-controlled means connected and operable to pass excess product, when demand by the consumer means is less than said rate, at a pressure above the demand pressure through said heat exchange device into said body of liquid; and valve-controlled means connected and operable to effect vaporization from said body of liquid at reducing pressure, when demand by the consumer means exceeds said rate, and passage of the resulting vapors through said heat exchange device to said product delivering means.

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