

pressures and rates and can deliver two or more products in high purity simultaneously, at consistent quality and consistent product gas pressure.

It is an object of the present ~~invention~~embodiments disclosed herein to provide a method of controlling a gas separation plant and a gas separation plant thus controlled where the disadvantages of prior art methods and plants, respectively, are absent or much reduced.

It is a specific object to provide a method and a plant which are each capable of delivering two or more products in high purity simultaneously.

It is a very specific object to provide a method and a plant which are each capable of delivering two or more products in high purity simultaneously even if the raw gas composition and/or pressure and/or volume vary. This plant or method shall more particularly also facilitate the delivery of consistent qualities, i.e. within narrow ranges of variation, preferably in continuous operation.

The method/plant of the present ~~invention~~disclosure shall be particularly flexible in a specific object and retentate and permeate qualities shall be controllable independently of each other. In a very specific object, it shall be possible for the capacity of the plant to be adjusted, for example conformed to changes in the raw gas flow, without having to free up or close down membrane areas, and/or to modulate the main pressure (pressure of the retentate product gas stream), to obtain product gas streams which without additional recompression are useful as a, preferably continuous, feed for a gas transportation line.

The control system of the present ~~invention~~disclosure shall preferably be simple and optionally integratable in existing plants.

Further objects not referred to explicitly are apparent from the overall context of the present description, examples, claims and drawings.

The objects of the present ~~invention~~embodiments disclosed herein are achieved by an apparatus according to Claims 1 and 17 and by a method according to Claim 9, respectively.

The method of the present ~~disclosure~~invention and the apparatus of the present ~~disclosure~~invention are characterized in that they concern an interconnected membrane arrangement comprising at least a feed stream separation stage (1), a retentate separation stage (2) and a permeate separation stage (3), wherein the second permeate stream (9a + 9b) of the retentate

separation stage (2) and the third retentate stream (10a + 10b) of the permeate separation stage (3) are recycled and mixed with the raw gas stream. By controlling the flow rates of the two streams (9a) and (10a) and hence the permeate pressure of the retentate separation stage (2) and/or the retentate pressure of the permeate separation stage (3), the inventors surprisingly succeeded in achieving the stated objects.

The inventors thereby succeeded in providing a method and a plant in each of which the purities and yields of the product streams of retentate separation stage (2) and of the permeate separation stage (3) can be controlled independently of each other. Very high yields coupled with very good purities are obtainable even in the event of fluctuations in the raw gas stream.

In a first aspect, there is provided an apparatus for separating gases, comprising as membrane separation stages at least a feed stream separation stage (1), a retentate separation stage (2) and a permeate separation stage (3) and also at least one compressor (4) arranged on the feed side of said feed stream separation stage (1) and/or at least one, preferably one or two, vacuum pump(s) arranged downstream of said feed stream separation stage (1), preferably on the permeate side of said retentate separation stage (2) in a second permeate stream (9a + 9b) and/or on the permeate side of said permeate separation stage (3) in a third permeate stream (11).

wherein

said feed stream separation stage (1) separates a feed stream (5), consisting of two or more components, into a first permeate stream (6) and a first retentate stream (7),

said retentate separation stage (2) divides said first retentate stream (7) into a second permeate stream (9a + 9b), wherein (9a) characterizes the part-stream upstream of a permeate control means (18) and downstream of said retentate separation stage (2) and (9b) characterizes the part-stream downstream of said permeate control means (18), and

said part-stream (9b) is supplied to said feed stream (5), and a second retentate stream (8) which is removed as product or further processed,

said permeate separation stage (3) divides said first permeate stream (6) into a third retentate stream (10a + 10b), wherein (10a) characterizes the part-stream upstream of a retentate control means (19) and downstream of said permeate separation stage (3) and (10b) characterizes the part-stream downstream of said retentate control means (19), and said part-stream (10b) is supplied to said feed stream (5), and a third permeate stream (11), which is removed as product or further processed or discarded,

characterized in that

— said second permeate stream (9a + 9b) comprises at least one permeate control means (18) with which the permeate pressure of said retentate separation stage (2) can be raised or lowered and which is controlled on the basis of measured values from one or more

measuring means (20a) in said first retentate stream (7) and/or one or more measuring means (20b) in said second retentate stream (8), wherein said measuring means are preferably different,

and/or

said third retentate stream (10a + 10b) comprises at least one retentate control means (19) with which the retentate pressure of said permeate separation stage (3) can be raised or lowered and which is controlled on the basis of measured values from one or more measuring means (21a) in said first permeate stream (6) and/or one or more measuring means (21b) in said third permeate stream (11), wherein the measuring means are preferably different.

In a second aspect, there is provided a method of controlling a gas separation plant as disclosed above characterized in that

- i. when the concentration of a less readily permeating component B, optionally also determined through a parameter correlating therewith, of said second retentate stream (8) falls below a predetermined setpoint value, the pressure of said second permeate stream (9a) is lowered by said permeate control means (18) until said concentration/parameter is back in the setpoint range,
- ii. when the concentration of a less readily permeating component B, optionally also determined through a parameter correlating therewith, of said second retentate stream (8) rises above a predetermined setpoint value, the pressure of said second permeate stream (9a) is raised by said permeate control means (18) until said concentration/parameter is back in the setpoint range,

and/or in that

- iii. when the concentration of a less readily permeating component B, optionally also determined through a parameter correlating therewith, of said third permeate stream (11) falls below a predetermined setpoint value, the pressure of said third retentate stream (10a) is raised by said retentate control means (19) until said concentration/parameter is back in the setpoint range,
- iv. when the concentration of a less readily permeating component B, optionally also determined through a parameter correlating therewith, of said third permeate stream (11) rises above a predetermined setpoint value, the pressure of said third retentate stream (10a) is

lowered by said retentate control means (19) until said concentration/parameter is back in the setpoint range.

In a third aspect, there is provided a method of controlling a gas separation plant as disclosed above characterized in that

- v. when the volume flow of said first retentate stream (7) increases, the pressure of said second permeate stream (9a) is lowered by said permeate control means (18) until a property of said second retentate stream (8) which is correlated by a calibration curve with said volume flow of said first retentate stream (7), preferably the composition of said second retentate stream (8), is back in the setpoint range,
- vi. when the volume flow of said first retentate stream (7) decreases, the pressure of said second permeate stream (9a) is raised by said permeate control means (18) until a property of said second retentate stream (8) which is correlated by a calibration curve with said volume flow of said first retentate stream (7), preferably the composition of said second retentate stream (8), is back in the setpoint range,

and/or

- vii. when the volume flow of said first permeate stream (6) increases, the pressure of said third retentate stream (10a) is raised by said retentate control means (19) until a property of said third permeate stream (11) which is correlated by a calibration curve with said volume flow of said first permeate stream (6), preferably the composition of said third permeate stream (11), is back in the setpoint range,
- viii. when the volume flow of said first permeate stream (6) decreases, the pressure of said third retentate stream (10a) is lowered by said retentate control means (19) until a property of said third permeate stream (11) which is correlated by a calibration curve with said volume flow of said first permeate stream (6), preferably the composition of said third permeate stream (11), is back in the setpoint range.

In a fourth aspect, there is provided a biogas plant comprising an apparatus as disclosed above.

The method of the present inventiondisclosure further makes it possible to keep the main pressure (retentate pressure of retentate separation stage (2)) constant, so the plant of the present inventiondisclosure can be connected to a gas transportation line without additional compression means.

The plant of the present inventiondisclosure is particularly useful for processing raw gas streams from biogas plants. In plants of this type, the amount of raw gas generated and the composition of the raw gas change very often. The fluctuations are readily compensated out by the control provided by the present inventiondisclosure.

The control provided by the present inventiondisclosure is simple and can be integrated in existing gas separation plants.

The method of the present inventiondisclosure is also flexible because two or more different kinds of sensors can be used alone or together. Compositions of streams can be used to control the pressures in the separation stages (2) and (3), as well as flow rates of streams supplied to these separation stages. Notably with the use of flow rate sensors an economical, fast, accurate and simple method is made available after calibration.

Consequently the present inventiondisclosure provides apparatuses according to Claims 1 and 17 and a method according to Claim 9. Preferred embodiments are protected in the dependent claims.

The present inventiondisclosure will hereinbelow be described in detail. First some important terms will be defined.