

Filter module, filter unit and filter process for gas separation

The invention provides a filter module for gas separation, a filter unit comprising said filter modules and a filter process for gas separation.

Background

The technology of gas separation is widely known in the prior art, as well as the use of mainly cylindrical filter module with inner filter cartridges assembled to a filter stack and used in a filter plant. A process for production of high-performance hollow fibers for gas separation is described in WO 2014/202324 A1 and WO 2011/9919 A1. In one embodiment such hollow fibers having an inner diameter of 200-1000 μm being grouped in a bundle, both ends adhered with a resin and placed inside a usually metal cartridge having several orifices somewhere in the central section.

The cartridge is core element of the filter module placed and insulated in an e.g., metal filter housing. At both ends inside the filter housing there are terminal inner chambers vis-a-vis the terminal end of the cartridge, one feed chamber for the crude gas and one outlet chamber for retentate gas. Permeate gas travels through the walls of the hollow fibers and assembled in a ring chamber located between the cartridge housing and the module housing. However, regarding crude gas to be treated the gas flow through the filter module and filter cartridge can be different, and the feed of crude gas takes place through a central port into the central ring chamber and permeate gas is released on at least one of the terminal inner chambers and released through a suitable outlet port into a collecting manifold.

Further analogous basic constructions of filter modules are known, such as spiral wound filter module. Such spiral filter modules having a flat filter membrane wound round a metal core tube. Such filter modules are e.g., described in EP 3 328 521 B1. Such filter modules are arranged in parallel, and each filter module is connected to at least one central feed line for the crude gas, one central outlet line for the permeate gas and one for the retentate gas. In an alternative not so common solution, the bundle of filter fibers or the spiral filter membrane is not placed in a separate cartridge housing but mounted in a terminal flash and/or resin ring and insulated and placed as such in the outer filter housing.

US 11,534,722 B2 describes a typical filter stack for gas separation with more than 20 cylindrical filter modules, wherein five groups of parallel filter modules are arranged on top of each other. Each filter module is connected to a manifold at both terminal ends and at a

central part of the body. In case of maintenance and/or change of one single inner filter cartridge, at least one manifolds need to be disassemble.

One disadvantage of the known filter modules is the extensive and time-consuming maintenance, e.g., in case of exchange of the filter cartridge. An exchange needs sufficient space in axial direction for the entire length of the cartridge. Especially, it is difficult to align ends of bigger filter module together with one common manifolds. For small filter modules using flexible braid reinforced hose might be a suitable solution, however for large filter modules this solution is not favorable due to large bend diameter needed. Thus, according to prior art a manifold branch connection to every filter module is needed, as described e.g., in US 11,534,722 B2.

As a solution to optimize maintenance activities, WO 91/16124 A1 offers a solution with a partitional central line, where in each filter module comprises a part of a central gas line. This solution increases the number of parts and the filter module as such becomes technical more complex and is thus commercially negative.

The object of the present invention is to provide a filter module, a filter unit, and a method to run a gas filter process in absence of the mentioned disadvantages.

These requirements could be solved by the inventive filter module (filter unit) for gas separation, comprising at least an outer filter housing (filter housing), a filter cartridge (filter cartridge) having an outer diameter (D_{FC}), wherein the filter housing having two terminal sections and a central section, wherein filter housing and filter cartridge having a joint longitudinal axis A, and wherein an inner (terminal) chamber is located inside each terminal section, and an inner ring chamber is located between the filter cartridge and the central section of the filter housing, wherein a central connector with a flow axis B is located at the central section leading to the inner ring chamber, wherein at least one of the two terminal sections having two (terminal) connectors with a flow axis C leading to the inner chamber, and wherein at least one terminal section is furnished with a closure element allowing to insert and/or pull the filter cartridge in direction of the longitudinal axis A.

In one advantageous solution, the (terminal) end section is formed as a cap or dome segment. The connectors leading to an inner chamber or inner room of the filter module. Thus, a suitable orifice is placed where the respective terminal or central connectors are placed.

The closure element having an outer diameter D_{CE} , wherein D_{CE} is bigger than the outer diameter of the filter cartridge D_{FC} allowing to insert and/or pull the filter cartridge in direction of the longitudinal axis A without any other effort than removing the closure element as such. In a preferred embodiment, the closure element and the filter housing are designed to clear a free inner diameter of the filter housing bigger than the outer diameter of the filter cartridge D_{FC} .

Thus, the connected inner chambers and the related terminal connectors at each end of the filter module form a joint, inner (crude or retentate) gas line, and analogously, the inner ring chambers and the related central connectors form a joint, inner gas line for the entire (permeate) gas flow.

Preferably, there is no need disassembling and/or dismantling the filter housing and/or any central manifold or gas line to pull or insert the filter cartridge. The closure element comprises and/or interacts with mounting device for gas closed positioning at the terminal section, and one or more gaskets or sealings for gastight closure are implemented. However, the terminal connector leading to the inner terminal chamber is not part of and/or located at the closure element and the closure element can be dismantled at the place of use, without affecting the connection of the neighbored terminal connectors at least at one side of the filter module, preferably at both sides of the filter module.

Place of use means the filter module arranged and mounted for filtering crude gas, such as but not limit to e.g., (polluted) air, biogas, natural gas, waste gas of a dumpsite.

The housing can comprise at least one mounting element for assembling or grouping one filter module next to at least one further filter module to build a filter unit (filter unit) and/or for mounting at a carrier or frame element as part of a filter unit.

With other words, at least at one end of the filter module, or at the central body comprises an inlet connector and an outlet connector. Thus, gas can flow through an inner chamber of the filter housing in at least one of the following such a way:

- Incoming gas is diverted in one portion to be treated in the respective filter cartridge and the remaining portion is allocated to the connected neighbored filter module to be treated there or diverted and treated in the same way.
- Outflowing gas from the filter cartridge is collected in an inner chamber as the first portion of (treated) gas and another (second) portion of gas, preferably of the same kind, coming from a connected neighbored filter module entering this inner

chamber via an inlet connector as the second portion of gas. Both gas portions are mixed to a certain degree in this inner chamber and exit this inner chamber at the outlet connector, preferably at the opposite side of the respective inner chamber.

Outflowing gas of the filter cartridge means permeate gas or retentate gas.

The term "flow axis" shall mean the orientation and place of the (central) axis of the main flow in the main flow direction. However, this term is not meant in a mathematical sense having zero height, but in a describing way for better understanding. Thus, multiple axes in one plane E might be physically located in a narrow corridor.

A connector leading to an inner chamber and/or an adjacent connector can comprise a (dis-)mounting device and/or being structured for mounting and dismounting, such as but not limit to e.g., flange, (circumferential) channel, protrusion, clamping ring. The (dis-)mounting device is preferably located at the distal end of the connector.

In an alternative embodiment, a connector is permanently connected at least with one distal end in the respective (side) wall of a filter housing by a connection, such as, but not limited to e.g., a welding connection or solder connection. In one preferred embodiment, as show and described together with the filter unit comprising two or more filter module, at least one connector is permanently connected at both distal ends with the wall and/or the filter housing of one filter module of a pair of filter module.

In another favourable embodiment the connector is plugged in the (side) wall and/or housing, wherein an isolation is at least located at the plugged end of the connector, such as but not limit to e.g., O-ring, sealing plate, gasket etc. As an alternative solution, the connector and the orifice to the inner chamber can comprise threads, and the connector can be screwed in the (side) wall and/or filter housing for gastight connection. As mentioned above, an isolation can be foreseen if needed.

As described herein after and more in detail also in conjunction with the filter unit, the passage of gas through the terminal sections and/or the central section of the filter modules, a much higher density of filter modules in transversal and in vertical direction due to the fact that no disassembly of the filter module as such or removing of manifold is needed for regularly maintenance, e.g. such as pulling or inserting of a filter cartridge. Moreover, the compact technical design offers a broad variety of preproduction and preassembly of groups of filter modules and/or filter units as described herein after, since even a large number of filter modules afford only one removable connection to one of the central gas lines.

According to another favorable embodiment two terminal connectors located at each terminal section leading to the respective inner (terminal) chamber. Preferably, the flow axes C of the terminal connectors at both ends of the filter module have the same orientation and are laying and defining one common (theoretical) plane. According to this embodiment, at each terminal section and the respective inner chamber, infeed of one portion of gas is done by means of the one connector and the outlet of another portion of gas is done by means of the other connector (outlet connector).

According to another favorable embodiment two central connectors located at the central section leading to the inner ring chamber. Therein each of the central connectors comprise one central flow axis B. In a preferred embodiment, the flow axis B of the central connector having the same orientation and lies within on common plain, preferably in one common plain of at least one terminal connector. Most preferrable, all the flow axes B, C have the same orientation and/or are parallel to each other.

According to another favorable embodiment the filter module comprises axes as follows; a common theoretical plane is defined by the longitudinal axis A and the flow axis B of the central connectors and/or the flow axis C of the terminal connectors. As mentioned above, the term "plane" or "plane is defined by" means the respective axis are within the same (theoretical) plane. Nevertheless "plane" shall not be considered and/or interpreted in a mathematical sense. "Plane" shall mean "substantially a plane" or a very small corridor in which the respective axes are jointly located.

According to another favorable embodiment the flow axis C of at least one of the terminal connectors and/or the flow axis B of the central connectors is oriented transfers to the longitudinal axis A. The flow axes of the connectors are preferrable in an 90° ankle to the longitudinal axis A of the filter module.

It was identified as beneficial when every flow axes are parallel to each other, and most beneficial when additionally, the flow axes are transfers (roughly 90° ankle) to the flow axis A in one common plane.

This leads to perfect filter units and filter plants having the smallest footprint and the highest ratio R of filter surface to (filter) equipment volume. This is archived with no concession regarding maintenance and/or accessibility of the filter unit and/or a single filter module.

According to another advantageous version, the filter module comprising one or two manifolds connecting the filter modules, wherein one manifold is meant for collecting or

distributing one of the following gases as stated; one manifold for permeate gas, one manifold for crude gas, and/or one manifold for retentate gas. Thus, instead of a joint, inner gas line formed by the connected (inner, ring) chambers and the related (terminal, central) connectors, one or two manifolds are implemented and used.

According to another favorable embodiment the filter module comprises one of the following alternatives;

- the first terminal section with the respective inner (terminal) chamber is the feed section for rough gas and the second, opposite terminal section with its inner (terminal) chamber is the retentate section for the release collection and release of retained portion of gas, and wherein the inner ring chamber is the permeate section for the collection and release of the permeated portion of gas via the central connector;
- the central section with the respective inner ring chamber is the feed section for rough gas, one terminal section with its inner (terminal) chamber is the retentate section for the collection and release of retained portion of gas via the respective terminal connectors, and wherein the second terminal section is the permeate section for the collection and release of permeated portion of gas via the terminal connectors.

Generally, the type or design gas filter is not limited and can be a hollow fibres filter having a bundle of multiple hollow fibres membrane, as gas separation membrane. These hollow fibres (membrane) can be oriented parallel to each other or wound on a central, inner core element, having at least one opening on the outer wall and serves as a gas inlet or outlet. As an alternative, the filter can be formed spiral filter or pocket filter having flat filter material spirally wound on the core element. Preferable the filter cartridge comprises an outer cartridge housing, usually made of metal, e.g., stainless steel or aluminium, or a highly resistance material regarding heat and fluid substances, such as but not limit to e.g., polycarbonate, polysulfone, polyurethane. Preferably, the outer cartridge housing comprises at each end a ring portion and/or flange portion, sealable against the inner wall of the filter housing. As an advantage, this ring and/or flange portion forming at least a part of the inner, terminal chamber at the respective end of the filter module.

The invention comprises also a filter unit comprising at least two filter module next to each other, preferable placed in parallel to each other, wherein each filter module comprising at least an outer filter housing, a filter cartridge having an outer diameter (D_{FC}), wherein the filter housings having two terminal sections and a central section, wherein filter housings and filter cartridge having a joint longitudinal axis A, and wherein

an inner (terminal) chamber is located inside each terminal section, an inner ring chamber is located between the filter cartridge and the central section of the filter housing, wherein a central connector having a flow axis B which is located at the central section leading to the inner ring chamber, and wherein both filter modules having at least one terminal connector with a flow axis C at each terminal section of the respective filter housing leading to the respective inner (terminal) chamber.

At least one of the at least two filter modules is built according one of the embodiments or versions as mentioned herein, and at least one (direct) connection is located between two filter modules leading from one terminal section of the first filter module to the terminal section of the other filter module, preferably any filter module is built according to one of the previous claims. With other words, at least two (terminal) inner chambers of the same kind of two filter modules are directly connected by one connector. "Chamber of the same kind" means, due to the filter type and intended flow direction inside the filter module, in the respective chamber it is intended guiding the same kind of gas, such as crude gas, permeate gas or retentate gas.

Thus, in case of a hollow fibres filter module, wherein the hollow fibres are parallel, the inner terminal chamber at the feed side forms the crude gas chamber of the filter module and is connected to at least one crude gas chamber of the neighbouring filter module via a (crude gas) connector. Analogously, the inner terminal chamber at the outlet side forms the retentate gas chamber of the filter module and is connected to at least one retentate gas chamber of the neighbouring filter module via a (retentate gas) connector. The central inner ring chamber forms the permeate gas chamber and is analogously in communication with at least one other permeate gas (ring) chamber. One filter module is beneficially connected directly with one or two neighbouring filter modules as described, but usually with no more than two filter modules.

It is known in the art to recycle and/or to mix gas of different types, however this is not in focus of this invention and usually not meant when describing gas flow, gas chambers and/or gas lines, unless described explicitly different. "Direct connection" means just one to one, no connection via a (separate) tube or line with multiple outlets as a manifold. Moreover, "to other filter module" shall mean in direct neighbourhood as a cascade from one filter module to the other filter module. The filter modules of one filter unit are connected by an integral or inner gas line, built out of terminal connectors and the inner

(terminal) chambers of the respective terminal sections at least at one end, preferably at both ends.

The connection between two filter modules of one filter unit can be built as one part, pipe, or piece. Alternatively, the connection can comprise both connectors and can be built by both connectors facing each other. A "connection" shall include an appropriate orifice, hole, or cut out in the respective side wall of the filter housing leading to the respective inner (gas) chamber, not mentioned in detail herein.

In a preferred embodiment the filter unit has one main feed connector as inlet and two main outlet connectors, one for retentate gas and one for permeate.

Thus, the filter modules are preferably connected by connectors in a way that crude gas might flow from filter module $m=1$ to filter module $m = n$ inside the respective inner (terminal) chambers, or in counter direction. However, the flow of the crude gas does not limit the flow direction of

- permeate gas through the ring chambers linked among each other by connectors, which might flow serially from filter module $m = n$ to filter module $m = 1$, or in counter direction; and/or
- retentate gas through the respective inner (terminal) chambers linked among each other by connectors, which might flow serially from filter module $m = n$ to filter module $m = 1$, or in counter direction.

According to a preferred embodiment of the process and best accessibility of the filter module, maintenance, and control of the process, central (total) feed of crude gas, central (total) collection of permeate gas, and central (total) collection of retentate gas is located at the same filter module, either the first ($m = 1$), or the last ($m = n$).

The filter modules of one filter unit are preferably built identically, so the at least one filter module might comprise connectors leading one of the inner chambers not used. Such an inactive or unused connector can be closed by means of but not limited to e.g., a blind cap or suitable plug device.

As an advantage, these passages of gas through the terminal sections and/or the central section of the filter modules facilitates a much higher density of filter module in transversal and in vertical direction. Moreover, no disassembly of a single filter module or removing of a main gas line is needed for maintenance, e.g., such as pulling or inserting of a filter

cartridge. The inventive compact technical design of the filter unit and/or a group of x filter unit, i.e., a filter system, offers a brought variety of preproduction and preassembly of filter units. This is achieved because even a large number of filter modules in one filter unit and/or a filter stack with multiple filter units requires only one or a very limited number of removable central connections with central gas lines. As another advantage, filter housing and the entire piping and erecting at the plant site or preassembly in a see container can be done independent of the filter cartridges. Filter cartridges can be inserted at any point time in the filter housing without affecting the rest of the filter system and/or plant.

The decrease of mounting places can be demonstrated with the following example. A filter system known in the art with five filter modules has 15 branches and 15 connections to three manifolds and the respective main connections is difficult to adjust and preproduction is hardly possible. All modules and manifolds must be individually supported and aligned and restrained against dynamic forces of the fluid/pressure inside. As one disadvantage all connections to the manifold are accessible and could in theory be disconnected while under pressure.

The inventive filter stack with the same number of filter modules being pre-connected and assembled as three filter units each having 5 filter modules, only three times feed, retentate and permeate connections are needed, when recycling and cross pipe are not considered. Moreover, as small filter system or a single filter unit having e.g., five or less filter modules does not need a manifold at all and can be preproduced and preassembled independently from the delivery of the filter cartridges.

According to another favorable embodiment of the filter unit a common theoretical plane is defined by the following axis of at least two filter modules;

the longitudinal axis A,

the flow axis B of the central connectors and/or

the flow axis C of the terminal connectors;

preferably any of the (flow) axis define the common theoretical plane of the filter unit.

The term "plane is defined by" means the respective axes are within the same (theoretical) plane as describe herein. Even though the filter module and the plane E can have any orientation such as horizontal, vertical, or tilted, the preferred orientation of the plane E is horizontal or vertical, and the longitudinal axes A are horizontal. This offers the best accessibility to the closure elements of at least one side of the filter modules. The filter modules of one filter unit are parallel, preferable the filter modules of all filter units of one filter system are parallel.

Through this arrangement only very limited space is needed to access the filter module in case of maintenance.

The filter unit can comprise another preferred embodiment, wherein (direct) connections by connectors are located between

- each neighboured terminal sections of the filter module; or
- each neighboured terminal sections of the filter module and each neighboured central sections.

Herein "neighboured" means in direct adjacent and connected position, arranged as a cascade from one filter module to the other filter module, inter alia established by the connectors. Thus, as described earlier, filter modules are connected via an integral or inner gas line, basically formed by

- terminal connectors and terminal inner chambers of at least one end and/or
- central connectors and (inner) ring chambers of the central sections. The direct connections are preferable built by one single connector or a pair of attached connectors.

According to another favorable embodiment the filter unit comprises at least two filter subunits, wherein the filter modules of each filter subunit have at least one direct connection and/or one pair of connectors between (neighboured) filter modules are welded. Preferably, the direct connections of at least two filter modules of one filter subunit is a permanent and non-removable connection.

As a beneficial alternative, the direct connection of at least two neighbouring filter modules is coupled with higher safety standard and/or stability than the connections between two filter subunits. The connection between two filter subunits can be a fast lock or clamping device allowing fast handling in case of maintenance. This distinction of the connections preferably means the ability for easy handling and easy opening by a person and shall not define different degrees of gas tightness in the intended field of use. Thus, the connectors between two filter modules of one filter subunit might comprise flanges with multiple screwing, at least partial adhesion and at its extreme, the single connector or the pair of connectors between at least two filter modules of one filter subunit is welded in. Most preferable a filter subunit is built as a vessel e.g., pressure vessel according national or regional pressure standard, such as but not limited to the German "Druckbehälterverordnung" (DruckbehV), AD 2000, European Pressure Vessel Guideline (2014/29/EU), 2023 ASME Boiler Vessel Code, API 510.

In case of welded connections, the distal end of two connectors can be welded together and/or welded in the respective wall of the filter housing in case of one single connector between two inner chambers. Thus, the connection can be built by both connectors facing each other. As mentioned herein above, a connection includes at least one orifice, hole or cut out in the respective side wall of the filter housing leading to the respective inner chamber. This detail is not mentioned or described in detail.

The huge benefit of filter subunits formed as pressure vessels, preferable welded pressure vessels, which are combined (connected) to form the final filter unit and/or filter system are the following;

- A producer can preproduce functional units, i.e., filter subunits, under perfect production conditions in-house, which facilitates secured high quality at high throughput,
- huge filter systems can be built hardly without limitations in volume or size by combining these (identical) filter subunits,
- the consumption of building volume as well as ground space (footprint) is minimised and/or
- in most of the jurisdiction receiving an allowance or approval for the filter subunits is sufficient (type approval) to erect filter system hardly of any size, which minimises the organisational requirement and the related time consumption.

Thus, the filter unit can comprise according one improvement of this embodiment at least two filter subunits comprising at least one removable mounting devise and/or being built as a removable mounting devise located at the distal ends of the connectors connecting two filter subunits. The removable mounting or connecting devise can be such but not limited to coupling connectors, collar flange, clamp collar etc. The same or an analogous removable mounting or connecting device can be provided at the main feed connector and/or (both) outlet connectors.

According to another favorable embodiment at least one carrier element arranging and/or carrying at least the filter module of one filter unit and/or filter subunit. Preferably the group of filter module defining one filter unit, or one filter subunit are adjusted and secure fixed in the carrier element. Moreover, the carrier element itself can comprise external mounting elements, wherein external mounting elements means mounting elements for the connection with another filter unit e.g., placed on top or underneath and/or for the

connection with shoring, pillar, or any kind of outer construction. A number of two or more connected filter units form a filter stack and a filter system shall mean a filter unit, or a filter stack connected to the main feed and outlet lines. Thus, a filter unit or stack can be preproduced at a construction site. The filter system is completed at the place of use, the place where the filter of crude gas is intended.

Preferably the carrier element is a steel sheet piece e.g., with bending edges allowing an easy stacking of filter modules. According one beneficial solution of the filter unit, cut-outs in the carrier elements communicate with a reduced diameter at the distal end of filter modules. This accomplishes a beneficial centring and adjustment of one filter modules at the carrier element. With suitable clamping elements, such as a clamp ring, the positioning inside the carrier element can be secured.

Preferably, the filter unit comprises at least two carrier elements, wherein an advantageous solution can be having at least one carrier element located at each terminal section of the filter modules. This solution can be beneficially completed by carrier elements made of steel or steel sheet piece e.g., with bending edges. Beneficially, the filter units comprise cut-outs in the carrier elements at both ends which communicate with a reduced diameter at the distal end of the filter modules at both ends. The filter modules are secured with suitable lock elements, such as but not limited to clamp rings.

The invention further comprises a process for gas separation of a crude gas, providing or having elements connected as follows;

- a) at least one filter unit comprising at least a number of N filter modules (placed and) working in parallel,
- b) a main gas feed line, a main retentate outlet line and a main permeate outlet line,
- c) connecting at least a first filter module of the filter unit to the main gas feed line for crude gas, the main retentate outlet line and the main permeate outlet line, wherein the following steps are comprised:
 - i) receiving and distributing crude gas flow volume through a gas line comprising inner chambers of at least two filter modules,
 - ii) collecting and draining off retentate gas flow volume through a gas line comprising inner chambers of at least two filter modules, and/or

- iii) collecting and drain off permeate gas flow volume through a gas line comprising inner chambers of at least two filter modules.

The gas line comprising inner chambers shall mean an integral part or section of the filter modules in question, different to a manifold located outside the filter unit and/or the filter modules, which works as outer distributor or collector, connected via single branches to the respective side of a filter housing.

In case of a process comprising at least step i), the process is of FIFO type, meaning first-in, first-out, because the first portion of crude gas is guided into the first filter element inside the inner terminal chamber and the remaining portion of crude gas is guided via the direct connection to the inner terminal chamber of the neighbouring filter module of the same filter unit. The analogous aspects apply for step ii) and iii) in case of implementation. However, the (main) flow direction through the inner gas lines, build at least by inner chambers and the respective connectors is generally not limited and can be organized according to local requirements, such as but not limited accessibility.

According to another most favorable embodiment of the process, the at least one filter unit is built according one of the embodiments and/or versions as mentioned herein.

Any aspect or benefit mentioned regarding the inventive devices, such as filter modules, filter units, filter stacks, filter systems shall apply identical or analogously to the process comprising and/or using said inventive devices, and vice versa.

One beneficial embodiment of the process can comprise the at least the following steps:

- Receiving the total volume of crude gas by the first filter module ($m = 1$) of n filter modules in total,
- Flow splitting of total volume of crude gas, meaning first flow splitting, in the filter housing of the first filter module into a first treatment flow or flow treatment volume and a first transfer flow or transfer flow volume to the second filter module ($m = 2$),
- Receiving the first transfer flow volume of crude gas by the second, neighbored filter module ($m = 2$),
- Flow splitting of first transfer flow volume of crude gas (second flow splitting) in the filter housing of the second filter module into a second treatment flow volume and a second transfer flow volume to the third filter module ($m = 3$), and so on, up to
- Receiving next-to-last transfer flow volume of crude gas by the last filter module ($m = n$),

- Treatment of the (total) next-to-last ($m = n-1$) transfer flow volume (fraction) of crude gas in the filter housing of the last filter module.

With other words, according to the total number n of filter modules, the crude gas is preferably divided also in n fractions, each fraction is treated in the respective filter module. The last filter module ($m = m_{\max}$) receives the total last fraction. Thus, the filter module with the highest consecutive number is defined as the filter module having the consecutive number $m = m_{\max} = n$.

The letter “ m ” means in the given context a placeholder for a whole consecutive number, beginning with 1. The letter “ m ” can be between 1 to 100, preferably between 1 to 50, most preferably 1 to 30. In the given context, a total number of filter modules is at least two. Accordingly, “ $m-1$ ” means a whole number m minus one, “ $m+1$ ” means a whole number plus one.

The numbers in lowered position, e.g. retentate gas “ $R_{n/m}$ ”, permeate gas “ $P_{n/m}$ ”, filter subunit “ 200_m ”, etc. shall have the analogous meaning as “ n ”- or “ m ”-numbering of the filter modules and/or shall be understood as related to the respective filter module.

“Treatment” means the intended gas separation or gas purification.

With other words, after each flow split one portion or fraction of crude gas is treated and the other portion of crude gas is guided via the connection to the neighbouring inner chamber of the respective neighbouring filter module. This steps or sequence of flow provided for crude gas can be beneficially combined with analogous steps or sequence of flows regarding the permeate gas and/or the retentate gas.

“Flow splitting in the filter housing” means the distribution of the gas flow of flowing gas volume inside the filter housing, which is not arranged by an outer manifold as gas collector line or gas distribution line.

Inside the last receiving filter module ($m = n$), the entire received gas flow is treated and no (further) flow splitting takes place.

Inventive devices and the process requires additional equipment, process units and/or process steps, such as but not limited to control unit; tank unit; housings; sensors, e.g., for pressure, temperature or mass flow; piping etc. These details are not described and not shown and can be implement according to local needs.

According to another favorable embodiment the process, the following steps or sequence of flow are made regarding the retentate gas, analogously to the steps mentioned above;

- Leading the (entire) volume of retentate gas R_n of the last filter module (i.e., filter module: $m = n$) to the next-to-last filter module (i.e. filter module: $m = n-1$),
- Receiving the (total) volume of retentate gas R_n of the last filter module by the next-to-last filter module (filter module: $m = n-1$) and merging it with the own volume of retentate gas R_{n-1} inside the next-to-last filter housing,
- Leading the merged volume of retentate gas R_{n-1} of the next-to-last filter module (filter module: $m = n-1$) to the subsequent filter module (filter module: $m = n-2$),
- Receiving the volume of retentate gas R_{n-1} of the next-to-last filter module (filter module: $m = n-1$) by the subsequent filter module (filter module: $m = n-2$) and merging it with the own volume of retentate gas R_{n-2} inside the filter housing, and so on up to
- Receiving the volume of retentate gas R_2 of the second filter module (filter module: $m = 2$) by the first filter module (filter module: $m = 1$) and merging it with the own volume of retentate gas R_1 inside the filter housing,
- Leading the total volume of retentate gas R_1 from the first filter module to the main retentate outlet line.

With other words, R_1 is the total volume of the retentate gas volume ($R_1 = R_{\max}$). Herein "last" is defined by the main feed connection to the main crude gas line, wherein the first filter module ($m = 1$) is the filter module direct connected to this main crude gas line. Analogously, the "last" filter module ($n = m = m_{\max}$) receives the remaining, last portion of crude gas of all parallel filter modules of one filter unit. Thus, as provided in the context of the text, m or n followed by "-" or "+" might indicate an arrangement relative to main flow direction, wherein "m-", "n-" indicates an arrangement of the respective part or module upstream to main flow direction and "m+", "n+" indicates an arrangement of the respective part or module downstream to main flow direction.

As an alternative the main flow direction of retentate gas in the inner gas line can be turned into counter direction. Thus, the entire volume of retentate gas leaves the last filter module, which is connected as an outlet to the main retentate gas line. In this case the entire retentate gas of the first filter module is received by the retentate chamber of the second filter module and merged with the retentate gas of the second filter module and so on.

According to the inventive process, the following steps or sequence of flow are made regarding the permeate gas P_n ;

- Leading the (entire) volume of permeate gas $P_{m=n}$ of the last filter module (filter module; $m = n$) to the next-to-last filter module (filter module; $m = n-1$),
 - Receiving the (entire) volume of permeate gas P_n of the last filter module (filter module; $m = n$) by the next-to-last filter module (filter module; $m = n-1$) and merging it with the own volume of permeate gas inside the filter housing,
 - Leading the merged volume of permeate gas P_{n-1} of the next-to-last filter module (filter module; $m = n-1$) to the subsequent filter module (filter module; $m = n-2$),
 - Receiving the volume of permeate gas of the next-to-last filter module (filter module; $m = n-1$) by the subsequent filter module (filter module) and merging it with the own volume of permeate gas inside the filter housing, and so on,
- up to
- Receiving the volume of permeate gas P_2 of the subsequent filter module (filter module; $m = n-2$) by the first filter module (filter module; $m = 1$) and merging it with the own volume of permeate gas inside the filter housing,
 - Leading the total volume of permeate gas P_1 of the filter unit from the first filter module to the main permeate outlet line.

According to the invention, the permeate gas P_m travels through the walls of the hollow fibers and is assembled in a ring chamber located between the cartridge housing and the module housing. Receiving of permeate gas P_m and merging it with own volume of permeate gas takes place in the ring chamber of the receiving filter module and permeate gas is channeled directly from ring room "m" to ring room "m-1". "Channeled directly" means any direct connection, such as but not limited to a conduit, tube, line, pipe etc., but excludes a collecting pipe or collecting manifold bypassing neighbored filter modules and/or the respective ring chambers.

As an alternative the main flow direction of permeate gas in the inner gas line can be turned into counter direction. Thus, the entire volume of permeate gas leaves the last filter module, which is connected as an outlet to the main permeate gas line. In this case the entire permeate gas of the first filter module is received by the permeate chamber of the second filter module and merged with the permeate gas of the second filter module and so on. Even though there is a preferred flow direction, splitting and merging as a cascade for crude gas, permeate gas and retentate gas stated herein, this shall not be understood as limiting.

Thus, the crude gas might flow from filter module $m=1$ to filter module $m = n$ inside the respective inner (terminal) chambers, or in counter direction. However, the flow of the crude gas does not limit the flow direction of

- the permeate gas through the ring chambers, which might flow serially from filter module $m = n$ to filter module $m = 1$, or in counter direction; and/or
- the retentate gas through the respective inner (terminal) chambers, which might flow serially from filter module $m = n$ to filter module $m = 1$, or in counter direction.

According to a preferred embodiment of the process and best accessibility of the filter module, maintenance, and control of the process, central (total) feed of crude gas, central (total) collection of permeate gas, and central (total) collection of retentate gas is located at the same filter module, either the first ($m = 1$) or the last ($m = n$).

The term "gaseous" means any non-solid and non-liquid form, such as but not limited to gas, steam, preferably gaseous steam. "Gaseous" as non-liquid form shall also exclude droplets or liquid spray.

As mentioned above, there might be cross connections between filter units of a filter stack of a filter system, such as recycling lines, recirculation lines, joined collection lines and/or manifolds for distribution or collection of main gas flow outside a single inventive filter unit.

The invention is further described in the following examples. Wherein the figures show the following;

Fig. 1: A single filter module in a vertical cut and two partial and enlarged views.

Fig. 2: A filter unit in a perspective view partial assembled.

Fig. 3: The filter unit of figure 2 assembled.

Fig. 4: A filter unit in a perspective view as another embodiment.

Fig. 5: A stack of filter units in a perspective view, and

Fig. 6: A filter unit as two further embodiments in perspective views I. and II.

The filter module 100 as shown in figure 1 comprises one outer filter housing 102, an inner filter cartridge 104 and a longitudinal axis A, indicated by the dotted line. The filter

housing 102 having two terminal sections 106, 108 one at each end of the longitudinal filter housing 102 and a central section 110, wherein the sections are indicated by curly brackets. At the first and second terminal section 106, 108 two terminal connectors 114 are located leading to the respective inner chamber 112 of the terminal sections 106, 108. Each terminal connector 114 having a central flow axis C. Analogously, at the central section 110 two central connectors 118 leading to the inner ring chamber 116 located between the cartridges housing 126 and the inner wall of the filter housing 102, best to be seen in both partial views. The central connectors 118 having central flow axis B.

It is obvious to the person skilled in the art, that the filter module 100 and the different axis, such as, but not limited to, the longitudinal axis A, the flow axes B, C might have any orientation. Preferably the longitudinal axis A having a horizontal or vertical orientation. In the example shown in figure 1, the longitudinal axis A and the central flow axes B, C are within one common plane E, defined by the x- and y-axes. However, the term "common plane" is not meant in a mathematical sense with no height or deviation in direction of z-axis. The common plane E shall support the description of the technical solution and might be a narrow corridor. In case some of the connectors, e.g. the connectors of one (gas) type are placed at the filter house off centre, there might be analogously more than one common plane or a group of parallel common planes.

The filter cartridge 104 comprises an outer cartridge housing 126, and at each terminal end one collar flange 140. The gas flow between the inner cartridge housing and the inner ring chamber 116 is enabled by means of a circumferential release area 128 comprising multiple orifices. The current inner arrangement of the respective membrane type, such as but not limited to a membrane of a bundle of hollow fibres are not shown, whereby such membrane types and solutions are generally known. Thus, the specific gas flow through the filter cartridge 104 depends on the respective membrane type. The collar flanges 140 are isolated inside the filter housing by means of O-rings 122. The collar flange 140 is connected and isolated to the cartridge housing 126 via at least one O-ring 124, and/or adhesively bonded.

In figure 1 the filter housing 102 is closed at the first terminal section 106 shown on the left side by means of a closure element 120. The terminal section 108 at the right side is in an open stage, the analogous closure element 120 is removed (not shown) and pulling of the inner filter cartridge is possible. The closure element 120 comprises a removable closure plate 130, three mounting segments 132 arranged at one end in a circumferential groove

138, wherein the closure plate 130 and the mounting segments 132 are fixed by means of at least one screw 134.

The closure element 120 and the filter housing 102 having a (e.g., inner) diameter (sufficient) bigger than the outer diameter D_{FC} of the filter cartridge 104, allowing to insert and/or to pull the filter cartridge 104 in direction of the longitudinal axis A.

The filter module 100 as shown in figure 1 to 5, wherein the filter cartridge 104 is a hollow fibre membrane. According to the current example, the crude gas, also named as feed gas, is introduced on the right side into the terminal section 108 by means of one terminal connector 114 in direction of the respective flow axis C. One portion of the crude gas enters the hollow fibres of the filter cartridge 104 and gas separation takes place. Retentate gas of said gas portion exists the hollow fibres and is collected at the opposite (left) side in the terminal section 106. The retentate gas leaves this terminal section 106 by means of one local terminal connector 114 in direction of the respective flow axis C. The permeate gas travels through the hollow fibres into the inner room of the cartridge housing 126, passes the orifices of the release area 128 and flows through the inner ring chamber 116. By means of one or both central connectors 118, the permeate gas exits the inner ring chamber 116 in direction of axis B. The remaining portion of crude gas, not entering the filter cartridge 104 is channelled to a neighbouring filter module 100 (figure 2, 3) by means of the other (opposite) terminal connector 114 of the right inner chamber 112 of the terminal section 108. Analogously the inner chamber 112 of the opposite terminal section 106 receives a volume flow of retentate gas from a neighbouring filter module 100 and the entire volume flow of retentate gas exits this terminal section 106 by means of the opposite terminal connector 114.

As also shown in the next figures in detail, the inner chambers 112 and the related terminal connectors 114 at each end of the filter module 100 form a joint, inner gas line 210, 210 (figure 2) for the entire crude gas flow and the entire retentate gas flow, respectively. Analogously, the inner ring chambers 116 and the related central connectors 118 form analogously a joint, inner gas line for the entire permeate gas flow. Moreover, due to the completely removable closure element 120 at one or at both front ends of the filter module 100, a maximum of density of filter module 100 can be reached, without external manifolds or with a very limited number of manifolds.

Figure 2 shows a Filter Unit 200 comprising five filter modules 100, comparable to the filter modules 100 as described together with figure 1 in a partial exploded view. The filter modules 100 are placed in parallel and numbered up from 100_1 to 100_5 , i.e. $m = 1$ to $m =$

5. Beside minor details, the filter module 100 are identically built. Central crude gas, forced by means of pump 216, enters filter module 100₁ as feed 220, indicated by an arrow. The crude gas flows through inner gas line 210 as indicated by a dotted arrow to each terminal section 106 of the filter module 100₁ to 100₅. Retentate gas R_m flows by means of the inner gas line 212 as indicated by a dotted arrow at the opposite ends of the filter module 100₁ to 100₅. Retentate gas R₁ to R₅ is collectively released out of the filter unit 200 as R₁, which is R_{total}.

Permeate gas P_m flows through inner gas line 214 as indicated by a dotted arrow to each of the inner ring chambers (not shown) of the respective filter modules 100₁ to 100₅. Analogously to the retentate gas R₁, permeate gas P₁ to P₅ is collectively released out of the filter unit 200 as P₁, which is P_{total}.

As mentioned earlier, the inner gas lines 210, 212 and 214 are multi-parts gas canals, comprising the respective inner chambers 112, 116 and connectors 114, 118 of the connected filter module 100₁ to 100₅. Different to the embodiment of figure 1, the terminal connectors 114 are joint connectors stackable at two neighbouring filter module 100. These joint connectors 114 are welded in neighboured filter housings 102, screwed-in, pressed-in and isolated in a useful way to hold the inner pressure as intended. The central connectors 118 are one sided welded in and connectable to another facing central connector 118 by means of a collar flange 140. Via the outlet 222 the retentate gas exits the first filter module 100₁ and thus the entire filter unit 200. Analogously, the permeate gas exits the first filter module 100₁ and thus the entire filter unit 200.

However, as e.g., shown in figure 4, as an advantage of the filter module 100 and the filter unit 200 with these filter modules 100, there is no need having the central outlets 222, 224 at the same side and/or same filter unit 100 as the (central) feed. Due to the local conditions at the place of use, any possible placement of the central feed 220 and outlets 222, 224 can be selected. Surprisingly it was found out, as long as the pressure drop Δp_{FM} in direction of the gas separation inside one filter module 100 is at least 1.5 higher than the pressure drop Δp_L in one of the central lines 210, 212, 214, no disadvantage with regard to the overall performance, mainly regarding selectivity, the permeability and/or the permeance of the filter module 100 could be considered. In a typical hollow fibres filter module 100 for gas separation, the pressure drop Δp_{FM} inside one hollow filter module 100 is at least 8 to 12 times higher than the pressure drop Δp_L in one of the central lines 210, 212, 214.

The filter unit 200 as shown in figure 2 comprises carrier elements 250 at both ends, having clamping orifices 252 suitable for mounting of at least a portion of the respective terminal sections 106. For mounting purpose, the terminal sections 106 having a reduced outer diameter and an outer circumferential groove 150 in which the related clamping ring 256 can be placed and closed. The carrier elements 250 are designed as frames. This frame like carrier element 250 has an upper and a lower splay 254 suitable for stacking and mounting filter unit 200 on top of each other as shown in detail in figure 5. For mounting filter unit 200 on top of each other or at joint pillar 352 (figure 5), suitable cut-outs 258 are placed one the front side and at the splay 254 of the carrier element 250.

Equal to the filter module 100 as shown in figure 1, the central connectors 118 are built as sockets connectable by means of collar flanges 140.

The last filter module 100₅ has on its outer side, which is not shown in figure 2, no terminal and/or central connectors. As an alternative and for sake of identical production and reduction of variations, the connectors not needed are closed with a blind cap or end plug 234, as e.g., shown in figure 4.

In figure 3 the single final assembled filter unit 200 as described together with figure 2 is shown. The first filter module 100₁ is connected via a branch with a central gas line 280 as crude gas supply and/or any return line coming from another filter unit 200, a central gas line (outlet) for retentate gas and a central gas line (outlet) for the permeate gas. The filter unit 200 is shown in the stage of maintenance, while the filter module 100₄ is open, and the filter cartridge 104 is partially pulled out of the filter housing 102 in direction of the longitudinal axis A.

In figure 3 several benefits can be seen, such as:

- preassembling the entire filter unit 200 in an external production facility not necessarily at the place of use,
- preassembling a stack of multiple filter units 200₁ to 200_n, wherein n is a number in the range of 2 to 20, preferably 2 to 10 and most advantageous 2 to 5 and
- opening a single filter module 100 and replacing one filter cartridge 104 without any disassembly of dismounting of other filter module 100 and/or any central gas line (in/out).

The solution according to figure 4 is comparable to the one as previously presented.

However, one Filter module 200 is made of two filter sub-units 200₁, 200₂. Each filter sub-unit 200₁, 200₂ having several filter modules 100₁ to 100₃ arranged in parallel and each

filter sub-unit 200₁, 200₂ is welded together by weld seams 232 as one-piece connectors or socket connectors, and thus being a single piece (pressure) vessel. The single filter modules 100₁ to 100₃ of such a filter sub-unit 200₁, 200₂ as a vessel cannot be non-destructively separated from each other. Two filter sub-unit 200₁, 200₂ are connected to each other via removable connection means, such as collar flanges 140, forming the final filter unit 200 with 2 x 3 filter modules 100, oriented and working in parallel.

As a huge benefit of such a combined filter unit 200 made of two or more (pressure) vessels 200₁, 200₂, a specific local or national type approval can be achieved by a producer for a filter sub-unit 200₁, 200₂, and no additional type-approval is needed for the final filter unit 200, as long as only approved filter sub-units are combined with approved connectors.

Figure 5 shows a filter system 300 comprising four filter units 200₁ to 200₄, each made according to the filter unit 200 of figure 3. In an alternative solution, at least one of the filter units 200₁ to 200₄ is made as a welded vessel, as described in connection with figure 4 for a filter sub-unit. The filter units 200₁ to 200₄ are placed on top of each other, and each filter unit 200₁ to 200₄ has one single central feed, and one central outlet for retentate gas and permeate gas. The interconnections 310 between the filter units 200₁ to 200₄ are generally known in analogous way in the prior art, however these interconnections 310 and the central feed and outlet lines are placed in a perfect narrow and easy to access way at one side of the filter system 300. However, it is not needed that each filter unit 200_n has exactly five and/or the same number of filter modules as it's neighbours. The number of filter modules per filter unit of one filter stack can vary as necessary for the filtration process in question.

The filter system 300 is part of a filter plant 400 and connected with additional pre- and post-treatment units for the gas not shown in figure 5. As easy to be recognised in figure 5, even in this narrow arrangement of 20 single filter modules 100, grouped as four filter units 300, each filter module 100 is separately accessible without any interference in the rest of the filter system 300. The filter system 300 is placed on pillars 320.

The filter plant 400, the filter system 300, filter units 200 and/or single filter modules 100 afford additional equipment in case of use for a gas separation process generally known, such as but not limited to storage, automation, controlling, documentation, and comparable equipment, not described in detail herein.

Finally, the filter unit 200 shown in figure 6 having a number of filter units 100_1 to 100_n , whereby the (first) three filter modules 100_1 to 100_3 are shown. Different to the embodiments of the figures described earlier, the filter unit 200, according to the partial view I of figure 6, comprises one manifold 215 for permeate gas instead of an inner gas line for permeate gas and the inner gas lines 210, 212 are built as mentioned herein. The manifold 215 is connected to the inner ring chambers 116 (not shown) of each respective filter unit 100_1 to 100_3 by only one connector 217. The connectors 217 are branches of the manifold 215 wherein permeate gas from each ring chamber 216 of each filter module 100 is collected in the manifold 215 and exits at the central outlet 224 of the manifold 215.

Analogously, as shown in the partial view II of figure 6, the crude gas enters at the central feed 220 the (crude gas) manifold 211 and is allocated to each filter modules 100_1 to 100_3 by one branch or connection 217. Each branch or connector 217 of the feed manifold 211 leads in one inner terminal chamber 112 at the feed side of a filter module 100. In the partial view II of figure 6, a manifold 211 is shown at the feed side of the filter unit 200, however, as indicated in brackets, the analogous manifold can be built for collecting and releasing retentate gas at the outlet or retentate side of the filter unit 200 and/or the respective filter modules 100_1 to 100_n .

Thus, the branches of connectors 217 of the manifolds 211, 213 or 215 are tilted to or transfers to the flow axes A, B, C (not shown in fig. 6) of the connectors 114, 118 being part of the respective inner gas line 210, 212, 214. Preferably, as shown in the partial views I, II of figure 6, the connectors 217 and its flow axes A, B, C (not shown) of the respective manifold 211, 213 and/or 215 are oriented in direction of the z-axis, i.e. vertical to a (horizontal) plane E, defined by the flow axes A, B or C of the inner gas lines 210, 212 and/or 214 (not shown). Analogously to the solution presented regarding the terminal connectors 114 or the central connectors 118, the branches or connectors 217 of one manifold 211, 213 or 215 can be welded in or being connected by a removable device, such as but not limited to e.g., a screw, collar flange, clamp ring.

In general, further isolation elements for gas tight closure might be useful, as known in the prior art, such as but not limit to e.g., gasket, sealing ring, O-ring, press fittings, isolation fluids, solder.

References

- 100 filter module (FM)
- 102 filter housing (FH)
- 104 filter cartridge (FC)
- 106 section, terminal
- 108 section, terminal
- 110 section, central
- 112 chamber (inner/terminal)
- 114 connector, terminal
- 116 ring chamber, inner
- 118 connector, central

- 120 closure element
- 122 O-ring
- 124 O-ring
- 126 cartridge housing
- 128 release area, circumferential (with multiple orifices)
- 130 Closure plate
- 132 mounting segment
- 134 screw
- 136 lock ring
- 138 groove

- 140 collar flange

- 200 filter unit
- 202 filter Sub-unit
- 204 filter sub-unit

- 210 gas line, inner - for crude gas
- 211 manifold for crude gas
- 212 gas line, inner - for retentate gas
- 213 manifold for retentate gas
- 214 gas line, inner - for permeate gas
- 215 manifold for permeate gas
- 216 pump

217	connector, branch of manifold
220	feed, central for crude gas
222	outlet, central for retentate gas
224	outlet, central for permeate gas
230	flange connection
232	weldseam
234	end plug
250	carrier element
252	clamping orifice
254	bending edge
256	clamping ring
258	cut-out
280	gas line, central - for crude gas
282	gas line, central - for retentate gas
284	gas line, central - for permeate gas
300	filter system
310	interconnection line
350	filter stack
352	pillar
400	Filter Plant
410	gas feed line, main
412	retentate outlet line, main
414	permeate outlet line, main
A	Axis of filter module
B	Flow axis of 118
C	Flow axis of 114, 118
E	Plane
P _m	Permeate gas, also P ₁ to P ₅
R _m	Retentate gas, also R ₁ to R ₅

Claims

1. A filter module (100) for gas separation, comprising at least an outer filter housing (102), a filter cartridge (104) having an outer diameter (D_{FC}) and comprising a bundle of multiple hollow fibres,
wherein the filter housing (102) having two terminal sections (106, 108) and a central section (110), wherein filter housing (102) and filter cartridge (104) having a joint longitudinal axis A, and wherein an inner chamber (112) is located inside each terminal section (106),
and an inner ring chamber (116) is located between the filter cartridge (104) and the central section (110) of the filter housing (102), wherein
a central connector (118) with a flow axis B is located at the central section (110) leading to the ring chamber (116),
characterised by
at least one of the two terminal sections (106) having two connectors (114) with a flow axis C leading to the inner chamber (110), and wherein at least one terminal section (106, 108) is furnished with a closure element (120) allowing to insert and/or pull the filter cartridge (104) in direction of the longitudinal axis A, and wherein the filter module (100) comprises two central connectors (118) located at the central section (110) leading to the inner ring chamber (116).
2. Filter module (100) of claim 1, characterised by two terminal connectors (114, 118) located at each terminal section (106, 108) leading to the respective inner chamber (112).
3. Filter module (100) according one of the previous claims, characterised by a common theoretical plane defined by the longitudinal axis A and the flow axis B of the central connectors (118) and/or the flow axis C of the terminal connectors (114, 118).
4. Filter module (100) according one of the previous claims, characterised by the flow axis C of at least one of the terminal connectors (106, 108) and/or the flow axis B of the central connectors (118) is oriented transvers to the longitudinal axis A.

5. Filter module (100) according one of the previous claims, characterised by comprising one or two manifolds (211, 213, 215), wherein one manifold is meant for collecting or distributing one of the following gases as stated;
 - one manifold (215) for permeate gas,
 - one manifold (211) for crude gas, and/or
 - one manifold (213) for retentate gas.
6. Filter module (100) according one of the previous claims, characterised by one of the following alternatives;
 - the first terminal section (106) with the respective inner chamber (112) is the feed section for rough gas and the second, opposite terminal section (108) with its inner chamber (112) is the retentate section for the release collection and release of retained portion of gas, and wherein the ring chamber (116) is the permeate section for the collection and release of the permeated portion of gas via the central connector (118);
 - the central section (110) with the respective ring chamber (116) is the feed section for rough gas, one terminal section (106) with its inner (terminal) chamber (112) is the retentate section for the collection and release of retained portion of gas via the respective terminal connectors (114), and wherein the second terminal section (108) is the permeate section for the collection and release of permeated portion of gas via the terminal connectors (118).
7. Filter Unit (200) comprising at least two filter module (100) placed in parallel, wherein each filter module (100) comprising at least an outer filter housing (102), a filter cartridge (104) having an outer diameter (D_{FC}), wherein the filter housings (102) having two terminal sections (106, 108) and a central section (110), wherein filter housings (102) and filter cartridge (104) having a joint longitudinal axis A, and wherein an inner (terminal) chamber (112) is located inside each terminal section (106), a ring chamber (116) is located between the filter cartridge (104) and the central section (110) of the filter housing (102), wherein a central connector (118) having a flow axis B is located at the central section (110) leading to the ring chamber (116), and wherein both filter modules (100) having at least one terminal connector (114, 118) with a flow axis C at each terminal section (106, 108) of the respective filter housing (102) leading to the respective inner (terminal) chamber (112),

characterised by

at least one of the at least two filter modules (100) is build according one of the previous claims, and wherein at least one (direct) connection is located between two filter modules (100) leading from one terminal section (106) of the first filter module (100) to the terminal section (106) of the other filter module (100), preferably any filter module (100) is build according one of the previous claims.

8. Filter Unit (filter unit) (200) of claim 7, characterised by a common theoretical plane defined by the following axis of at least two filter module (100);
the longitudinal axis A,
the flow axis B of the central connectors (118) and/or
the flow axis C of the terminal connectors (114, 118);
preferably any of the (flow) axis define the common theoretical plane of the filter unit.
9. Filter unit (200) according one of claims 7 or 8, characterised by (direct) connections located between
 - each neighboured terminal sections (106, 108) of the filter module (100); or
 - each neighboured terminal sections (106, 108) of the filter module (100) and each neighboured central sections (110).
10. Filter unit (200) according one of claims 7 to 9, characterised by at least two filter subunits (202, 204), wherein the filter modules (100) of each filter subunit (202, 204) have at least one direct connection and/or one pair of connectors (114, 118) between filter modules (100) being welded.
11. Filter unit (200) according claim 10, characterised by at least two filter subunits (202, 204) comprising at least one removable mounting devise and/or being built as a removable mounting devise located at the distal ends of the connectors (114, 118) connecting two filter subunit (202, 204).
12. Filter unit (200) according one of claims 9 to 11, characterised by at least one carrier element (250) arranging and/or carrying at least the filter module (100) of one filter unit (200) and/or filter subunit (202, 204).

13. Filter unit (200) according claim 12, characterised by at least two carrier elements (250), preferably at least one carrier element (250) located at each terminal section (106, 108) of the filter modules (100).
14. Process for gas separation of a crude gas, providing
- a) at least one filter unit (200) comprising at least a total number of n filter modules (100) working in parallel, numbered from $m = 1$ to $m = m_{\max} = n$,
 - b) a main gas feed line (410), a main retentate outlet line (412) and a main permeate outlet line (414),
 - c) connecting at least a first filter module (110) of the filter unit (200) to the main gas feed line (410) for crude gas, the main retentate outlet line (412) and the main permeate outlet line (414),
 - i) receiving and distributing crude gas flow volume through a gas line (210) comprising inner chambers (112, 118) of at least two filter module (100),
 - ii) collecting and drain off retentate gas flow volume through a gas line (212) comprising inner chambers (112) of at least two filter module (100), and/or
 - iii) collecting and drain off permeate gas flow volume through a gas line (210) comprising inner chambers (118) of at least two filter module (100),
- characterised by**
- at least one filter unit (200) configured according to at least one of the claims 7 to 13 and/or at least a total number of n filter modules (100) configured according to at least one of the claims 1 to 6.
15. Process according claim 14, characterised by comprising the following steps;
- Receiving the total volume of crude gas by the first filter module (100_1 ; $m = 1$) of n filter modules (100) in total,
 - Flow splitting (first) of total volume of crude gas in the filter housing (102) of the first filter module (100_1 ; $m = 1$) into a first treatment flow volume and a first transfer flow volume to the second filter module (100_2 ; $m = 2$),
 - Receiving the first transfer flow volume (fraction) of crude gas by the second, neighboured filter module (100_2 ; $m = 2$),
 - Flow splitting (second) of first transfer flow volume of crude gas in the filter housing (102) of the second filter module (100_2 ; $m = 2$) into a second treatment flow volume and a second transfer flow volume to the third filter module (100_3 ; $m = 3$),
- up to
- Receiving the next-to-last transfer flow volume of crude gas by the last filter module

(100_n ; $m = n = m_{\max}$),

- Treatment of the (total) next-to-last transfer flow volume of crude gas in the filter housing (102) of the last filter module (100_n ; $m = n$), wherein
- n is a whole number and the total number of filter modules;
- m is a consecutive total number from 1 to n , with $m_{\max} = n$, wherein m indicates the position of the respective filter module, wherein m is preferably a whole number between 1 and 100, more preferably between 1 and 50, most preferably between 1 and 30.

16. Process according claim 14 or 15, characterised by

- Leading the volume of retentate gas (R_n) of the last filter module (100_n ; $m = n$) to the next-to-last filter module (100_{n-1} ; $m = n-1$),
 - Receiving the (total) volume of retentate gas (R_n) of the last filter module (100_n ; $m = n$) by the next-to-last filter module (100_{n-1} ; $m = n-1$) and merging it with the own volume of retentate gas inside the filter housing (102),
 - Leading the merged volume of retentate gas (R_{n-1}) of the next-to-last filter module (100_{n-1} ; $m = n-1$) to the subsequent filter module (100_{n-2} ; $m = n-2$),
 - Receiving the volume of retentate gas (R_{n-1}) of the next-to-last filter module (100_{n-1} ; $m = n-1$) by the subsequent filter module (100_{n-2} ; $m = n-2$) and merging it with the own volume of retentate gas inside the filter housing (102),
- up to
- Receiving the volume of retentate gas (R_2) of the second filter module (100_2 ; $m = 2$) by the first filter module (100_1 ; $m = 1$) and merging it with the own volume of retentate gas inside the filter housing (102),
 - Leading the total volume of retentate gas (R_1) from the first filter module (100_1 ; $m = 1$) to the main retentate outlet line (412), wherein n and m are defined according to claim 15.

17. Process according one of the claims 14 to 16, characterised by

- Leading the volume of permeate gas (P_n) of the last filter module (100_n ; $m = n$) to the next-to-last filter module (100_{n-1} ; $m = n-1$),
- Receiving the volume of permeate gas (P_n) of the last filter module (100_n ; $m = n$) by the next-to-last filter module (100_{n-1} ; $m = n-1$) and merging it with the own volume of permeate gas inside the filter housing (102),
- Leading the merged volume of permeate gas (P_{n-1}) of the next-to-last filter module (100_{n-1} ; $m = n-1$) to the subsequent filter module (100_{n-2} ; $m = n-2$),

- Receiving the volume of permeate gas (P_{n-1}) of the next-to-last filter module (100_{n-1} ; $m = n-1$) by the subsequent filter module (100_{n-2} ; $m = n-2$) and merging it with the own volume of permeate gas inside the filter housing (102),
up to
- Receiving the volume of permeate gas (P_2) of the second filter module (100_2 ; $m = 2$) by the first filter module (100_1 ; $m = 1$) and merging it with the own volume of permeate gas inside the filter housing (102),
- Leading the total volume of permeate gas (P_1) from the first filter module (100_1 ; $m = 1$) to the main permeate outlet line (412), wherein n and m are defined according to claim 15.