SEAL CARTRIDGE AND CENTRIFUGAL SEPARATOR

TECHNICAL FIELD

The invention relates to a seal cartridge for a centrifugal separator and to a centrifugal separator comprising a seal cartridge.

BACKGROUND

A centrifugal separator comprises a rotatable system including a centrifuge rotor arranged to be rotated about a rotational axis. Inside the centrifuge rotor there is a separation space wherein a separation aid e.g., in the form of a stack of frustoconical separation discs may be arranged. A fluid feed mixture is fed into the separation space and the stack of discs to be separated into at least a light phase and a heavy phase during rotation of the centrifuge rotor. The light and heavy phases may be continuously led out of the centrifuge rotor.

A mechanical hermetical seal may be arranged between a stationary structure of the centrifugal separator and the rotatable system for sealing a fluid path extending therebetween. A mechanical hermetical seal comprises two halves, one arranged with the stationary structure, and one arranged with the rotatable system. The two halves abut against each other to form the seal. One or more of fluid paths for the fluid feed mixture, the separated light phase, and the separated heavy phase may be mechanically hermetically sealed in this manner.

EP 3384993 discloses a seal assembly for providing a seal between a first zone and a second zone in a centrifugal separator. The seal assembly comprises a rotatable sealing member comprising a first sealing ring, a stationary sealing member comprising a second sealing ring and means for bringing the first and second sealing rings into engagement with each other. Various parts of the seal assembly, such as the first and second sealing rings, are provided as separate components that are assembled in the centrifugal separator to provide the seal between the first and second zones.

In the field of pharmaceuticals, biopharmaceuticals, biotechnology and thereto related fields, separation of substances from a liquid mixture such as, separation of cells from a cell culture mixture, are performed in a sterile environment. Disposable separation equipment made for single use i.e., for one batch or a limited number of batches, have been suggested for this purpose. For instance, US2011/0319248 discloses a single use centrifuge and WO 2015/181177 discloses a separator comprising an exchangeable inner drum. Such disposable separation equipment is supplied to a user in a sterile manner. Thus, a sterile

environment may be provided for the liquid mixture in the separator without sterilisation of the separation equipment at the production facility of the user.

In the context of disposable separation equipment, WO 2022/233539 discloses a modular centrifugal separator system comprising a base unit and arranged therein an exchangeable separation insert, an exchangeable tube kit, and an interface for fluid communication between the exchangeable separation insert and the exchangeable tube kit. The interface is formed by a sealing arrangement between a rotatable centrifuge rotor and a stationary liquid passage device of the centrifugal separator system. The exchangeable separation insert comprises a rotor casing forming a separation space, and a first half of the interface. The exchangeable tube kit comprises at least one tube for one of a liquid feed mixture, a heavy phase, and a light phase, and a second half of the interface. Thus, the sealing arrangement between rotatable and stationary parts is provided as two separate parts, which are assembled in the centrifugal separator system to form an operational sealing arrangement during use of the centrifugal separator system.

SUMMARY

It would be advantageous to provide a sealing arrangement that is easy to install in a centrifugal separator. In particular, it would be desirable to enable installation of a sealing arrangement in a centrifugal separator that prevents faulty assembly of the two halves of the sealing arrangement. To better address one or more of these concerns, one or more of a seal cartridge and a centrifugal separator having the features defined in one or more of the independent claims is provided.

According to an aspect there is provided a seal cartridge for a centrifugal separator, the centrifugal separator comprising a stationary structure and a rotatable system configured to rotate about a rotational axis, the seal cartridge being configured for sealing at least a first fluid flow path extending between the stationary structure and the rotatable system of the centrifugal separator. The seal cartridge comprises a first sealing unit and a second sealing unit. The first sealing unit is connectable to the stationary structure of the centrifugal separator. The second sealing unit is connectable to the rotatable system of the centrifugal separator and rotatable about the rotational axis during operation of the centrifugal separator. At least a portion of the first fluid flow path extends through the first and second sealing units and the first and second sealing units are arranged in sealing abutment to seal the first fluid flow path. The first sealing unit is arranged in a first casing portion, and the second sealing unit is secured in relation to the first casing portion such that the seal cartridge forms one entity.

Since there is provided a seal cartridge for a centrifugal separator, since the first and second sealing units are arranged in sealing abutment to seal the first fluid flow path, and since the first sealing unit is arranged in the first casing portion, and the second sealing unit is secured in relation to the first casing portion such that the seal cartridge forms one entity – the seal cartridge is configured for installation in a centrifugal separator as one single module. Accordingly, the seal cartridge forming one entity entails that the seal cartridge is handled as one single unit, which as such is placeable in a centrifugal separator and as such is removeable from a centrifugal separator.

Accordingly, faulty assembly of the first and second sealing units in the centrifugal separator is prevented.

More specifically, the seal cartridge can be offered as a replacement part or an exchangeable part for a centrifugal separator. The seal cartridge is provided, e.g. by the manufacturer of the centrifugal separator, as one module to a user of the centrifugal separator. The manufacturer thus, is able to ensure that the first and second sealing units are correctly assembled and correctly positioned in relation to each other. At a facility of the user, the seal cartridge is mounted in the centrifugal separator as one single module. In this manner, a proper functioning and proper sealing characteristics of the sealing arrangement of the centrifugal separator in the form of the seal cartridge is ensured.

The seal cartridge may be provided in a form devised for use in centrifugal separator which includes single use parts. In such instances, the seal cartridge may be provided as a sterile unit configured for single use. For instance, as part of a single use tube kit for the centrifugal separator.

In an alternative implementation, the seal cartridge may be provided in a form devised for traditional centrifugal separators configured for long term use of the different separator parts. Also in such a traditional centrifugal separator, an ensured correct assembly of the first and second sealing units by a manufacturer relieves the user of the centrifugal separator from assembling the first and second sealing units. For instance, this may be advantageous when the first and second sealing units are to be replaced e.g., during servicing of the centrifugal separator.

According to a further aspect there is provided a centrifugal separator comprising a seal cartridge according to any one of aspects and/or embodiments discussed herein.

Since the centrifugal separator comprises a seal cartridge of the kind discussed above, when the first and second sealing units of the centrifugal separator are to be exchanged, they are done so as one single module by exchanging the seal cartridge. Again, faulty assembly of the first and second sealing units in the centrifugal separator is prevented.

As mentioned above, the centrifugal separator may include single use parts or may be a traditional centrifugal separator configured for long term use of its different separator parts.

The centrifugal separator including single use parts may be configured for use in the field of pharmaceuticals, biopharmaceuticals, biotechnology, and thereto related fields. In the centrifugal separator, separation of substances from a liquid feed mixture such as separation of cells from a cell culture mixture, may be performed in a sterile environment. For instance, the liquid feed mixture may be formed by a cell culture mixture such as a fermentation broth including a cell culture. A separated light phase may be formed by fermentation broth without the cells or with only a minimum rest amount of cells and/or cell debris. A separated heavy phase may comprise the cells and cell debris suspended in fermentation broth.

The traditional centrifugal separator may be used for any of the numerous separation tasks that centrifugal separators are used for.

At a more general level, the centrifugal separator, whether including single use parts or parts configured for long term use, may be configured for separating a fluid feed mixture, such as a liquid feed mixture, into a light phase and a heavy phase. The separation is performed in a separation space defined within a centrifuge rotor of the rotatable system. A separation aid e.g., a stack of frustoconical separation discs or radially and axially extending sheets, may be arranged in the separation space.

The fluid feed mixture is led into the separation space concentrically with the rotational axis or radially close to the rotational axis. The separated light phase is led out of the separation space concentrically with the rotational axis or radially close to the rotational axis. The separated heavy phase may be ejected intermittently or continuously from a radially outer periphery of the centrifuge rotor. Alternatively, also the separated heavy phase may be led out of the separation space along the rotational axis or radially close to the rotational axis. According to some embodiments, a sludge phase may be separated from the fluid feed mixture and may be ejected intermittently from a radially outer periphery of the centrifuge rotor.

Accordingly, the first fluid flow path may be devised for conducting therethrough one of the fluid feed mixture, the separated light phase, and the separated heavy phase.

Accordingly, according to some examples, the centrifugal separator may comprise a stationary structure and a rotatable system delimiting a separation space. The first fluid flow path may be arranged in fluid communication with the separation space. The first casing portion of the seal cartridge may be connected to the stationary structure, and the second sealing unit of the seal cartridge may be connected to the rotatable system.

The seal cartridge may form an interface for conduits connected to the centrifugal separator. That is, one, two or more of the liquid feed mixture, the light phase, and the heavy phase may be fed to/from the centrifugal separator via the seal cartridge.

Accordingly, the seal cartridge may be configured for sealing further fluid flow paths, such as a second fluid flow path and optionally a third fluid flow path.

Together, the first and second sealing units form a mechanical hermetical seal since they are arranged in sealing abutment with each other. The sealing abutment may be provided between respective axial surfaces of the first and second sealing units. Accordingly, a mechanical hermetical seal is provided around the first fluid flow path.

If portions of one or more further fluid flow paths extend through the first and second sealing units in the seal cartridge, also such further fluid flow paths are mechanically hermetically sealed between the stationary first sealing unit and the rotatable second sealing unit.

A mechanical hermetical seal may alternatively be referred to as a mechanical end-face seal.

One or both of the first and second sealing units may be comprised of one or more parts. Such parts may include low friction parts, such as parts including PTFE and/or wear resistant parts, such as parts including silicon carbide.

Herein, unless otherwise defined, axial, radial, and circumferential references related to the rotational axis of the rotatable system.

The first casing portion of the seal cartridge may be configured to securely hold the first sealing unit therein. For instance, the first sealing unit may be secured in the first casing portion such that the first sealing unit is non-rotatable in relation to the first casing portion.

The first casing portion may be configured for being fixedly connected to the stationary structure of the centrifugal separator. Thus, the first sealing unit may be indirectly connectable to the stationary structure of the centrifugal separator via the first casing portion. Accordingly, the first casing portion may have properties suited for connection thereof to the stationary structure. For instance, the first casing portion may be made from a material that withstands forces associated with connection between parts, such as clamping forces. The first sealing unit on the other hand, may be selected to provide good sealing properties for sealing against the second sealing unit.

The second sealing unit is secured to the first casing portion in a manner that permits rotation of the second sealing unit about the rotational axis in relation to the first sealing unit and the first casing portion.

The second sealing unit may be directly or indirectly connectable to the rotatable system of the centrifugal separator.

According to some examples, the second sealing unit may be arranged in a second casing portion. The second sealing unit may be secured in relation to the first casing portion by the second casing portion being secured in relation to the first casing portion. This may be achieved e.g. by any specific securing means such as a screw, snap fit or a radially protruding element. In this manner, the second sealing unit may be devised for providing good sealing properties against the first sealing unit and the second casing portion may be devised for providing a durable connection between the first and second casing portions.

According to some examples, the first casing portion may comprise at least one radially protruding member engaging with the second sealing unit or with the second casing portion to secure the second sealing unit in relation to the first casing portion. In this manner, a connection between the first casing portion and the second sealing unit or between the first casing portion and the second casing portion may be provided that permits the second sealing unit and, in relevant cases, the second casing portion to rotate about the rotational axis.

Alternatively, the second sealing unit or the second casing portion may be indirectly secured in relation to the first casing portion. For instance, an intermediate member may be fixedly connected to the first casing portion to secure the second sealing unit to the first casing portion. A portion of the second sealing unit or the second casing portion may be arranged between the first casing portion and the intermediate member to be secured in relation to the first casing portion.

According to some examples, the first sealing unit may be axially biased against the second sealing unit. In this manner, a sealing engagement between the first and second sealing units may be ensured.

Alternatively, the second sealing unit may be axially biased against the first sealing unit to ensure the sealing engagement between the first and second sealing units.

According to some examples, the seal cartridge may comprise a first pipe portion protruding from the first casing portion. A portion of the first fluid flow path may extend through the first pipe portion. In this manner, a conduit may be connected to the seal cartridge for conduction a fluid therethrough to, or from, the centrifugal separator.

The conduit may comprise a flexible tubing and may form part of a sterile tube kit which also includes the seal cartridge. The tube kit may be configured for use in a modular centrifugal separator system.

Alternatively, the conduit may comprise a rigid pipe of an installation, of which the centrifugal separator may be a part.

An alternative to the first pipe portion may be to provide a threaded opening or a bayonet coupling in the first casing portion in connection with the first fluid flow path. Flexible tubing or a ridged pipe may be connected to the threaded opening or the bayonet coupling.

Further features of, and advantages with, the invention will become apparent when studying the appended claims and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

Various aspects and/or embodiments of the invention, including its particular features and advantages, will be readily understood from the example embodiments discussed in the following detailed description and the accompanying drawings, in which:

Fig. 1 schematically illustrates a section along a rotational axis of an example of a centrifugal separator,
Fig. 2 schematically illustrates a section through a seal cartridge of a centrifugal separator,
Figs. 3a and 3b schematically illustrate first and second sealing units of the seal cartridge shown in Fig. 2,
Figs. 4a – 4c schematically illustrate an example of a seal cartridge for a centrifugal separator,
Figs. 5a – 5d schematically illustrate an example of a centrifugal separator, and
Figs. 6a and 6b schematically illustrate sections through portions of a centrifugal separator.

DETAILED DESCRIPTION

Aspects and/or embodiments of the invention will now be described more fully. Like numbers refer to like elements throughout. Well-known functions or constructions will not necessarily be described in detail for brevity and/or clarity.

Fig. 1 schematically illustrates a section along a rotational axis 6 of an example of a centrifugal separator 2. The centrifugal separator 2 is configured for separating a fluid feed mixture into a light phase and a heavy phase. As discussed above, also a sludge phase may be separated for intermittent discharge in the centrifugal separator 2.

The centrifugal separator 2 comprises a centrifuge rotor 4. The centrifuge rotor 4 is arranged to rotate about the rotational axis 6.

The centrifuge rotor 4 is provided with a separation space 3. A separation aid, exemplified by a stack 5 of frustoconical separation discs 7, is arranged inside the separation space 3.

The centrifugal separator 2 further comprises a spindle 8 connected to the centrifuge rotor 4 and arranged to rotate the centrifuge rotor 4 about the rotational axis 6. The centrifuge rotor 4 and the spindle 8 form part of a rotatable system 9 of the centrifugal separator 2. Accordingly, the centrifugal separator 2 comprises the rotatable system 9, which delimits the separation space 3.

The spindle 8 forms part of a drive arrangement 10 of the centrifugal separator 2, which drive arrangement 10 is arranged to rotate the centrifuge rotor 4 about the rotational axis 6. In the illustrated embodiments, the drive arrangement 10 further comprises an electric motor 11. The centrifuge rotor 4 is attached to the spindle 8. The spindle 8 forms part of the electric

motor 11, i.e. the centrifuge rotor 4 is directly driven by the electric motor 11. Thus, the drive arrangement 10 may rotate the centrifuge rotor 4 about the rotational axis 6.

Alternatively, the drive arrangement 10 may comprise a spindle connected to the centrifuge rotor 4, an electric motor, and a transmission arranged between the electric motor and the spindle.

The centrifugal separator 2 further comprises a housing 12, which at least partially encloses the centrifuge rotor 4. The housing 12 forms part of a stationary structure 13 of the centrifugal separator 2. Accordingly, the centrifugal separator 2 comprises the stationary structure 13.

The centrifugal separator 2 comprises a sealing arrangement, in the form of a seal cartridge 14 arranged between the stationary structure 13 and the rotatable system 9. The seal cartridge 14 is configured for sealing at least a first fluid flow path 16 extending between the stationary structure 13 and the rotatable system 9. The first fluid flow path 16 is arranged in fluid communication with the separation space 3.

Accordingly, the seal cartridge 14 forms an interface between the rotatable system 9 and the stationary structure 13.

The seal cartridge 14 comprises a first sealing unit 20 and a second sealing unit 22. The first sealing unit 20 is connected to the stationary structure 13 and thus, is stationary during use of the centrifugal separator 2. The second sealing unit 22 is connected to the rotatable system 9 and accordingly, rotatable about the rotational axis 6 during use of the centrifugal separator 2.

The first sealing unit 20 is arranged in a first casing portion, see further below e.g., with reference to **Fig. 2**, and the second sealing unit 22 is secured in relation to the first casing portion such that the seal cartridge 14 forms one entity.

Thus, the seal cartridge 14 can be handled as one single module e.g., when the centrifugal separator 2 is disassembled and assembled during servicing thereof. The seal cartridge 14 can form one spare part of the centrifugal separator 2 and accordingly, can be supplied as such by a manufacturer.

For instance, as indicted in **Fig. 1**, in a traditional centrifugal separator 2 comprising parts, such as the seal cartridge 14, configured for long term use, the seal cartridge 14 may be accessed for removal and/or replacement via a removable portion 12' of the housing 12. In a centrifugal separator 2 comprising single use parts, of which the seal cartridge 14 may form one part, the seal cartridge 14 may form part of an exchangeable tube kit, see e.g. below with reference to **Figs. 5a – 5d**.

In the illustrated example, the first fluid flow path 16 extends concentrically with the rotational axis 6 between the stationary structure 13 and the centrifuge rotor 4 of the rotatable system 9. Further, in the illustrated example, a second fluid flow path 18 extends radially outside the first fluid flow path 16 between the stationary structure 13 and the centrifuge rotor 4.

During use of the centrifugal separator 2, each of the first and second fluid flow paths 16, 18 is arranged for conducting one of a fluid feed mixture, a separated light phase, and/or a separated heavy phase to and from the separation space 3. That is, the first and second fluid flow paths 16, 18 are arranged in fluid communication with the separation space 3.

In the illustrated examples, the fluid feed mixture is conducted through the first fluid flow path 16 into the separation space 3 and the separated light phase is conducted through the second fluid flow path 18 from the separation space 3.

The third of the fluids, i.e. the heavy phase in the illustrated example, may be conducted from the separation space 3 via a third fluid flow path (not shown).

In a known manner, during separation of the fluid feed mixture in the centrifugal separator 2, the fluid feed mixture is lead via the first fluid flow path 16 to a centre of the centrifuge rotor 4 and from the centre, into the separation space 3 and the disc stack 5. The fluid feed mixture is separated into the light phase and the heavy phase. The separated light phase flows radially inwardly between the separation discs 7 towards the rotational axis 6 and out of the centrifuge rotor 4 via the second fluid flow path 18. The separated heavy phase flows radially outwardly between the separation discs 7 towards a periphery of the separation space 3 and out of the centrifuge rotor 4 via the non-shown third fluid flow path.

Centrifugal separators utilising these separation principles are known and come in a number of different types and sizes. Centrifugal separators 2 of this kind are used for multi-batch processing i.e., using parts that are configured for long term use, such as in the centrifugal

separator 2 shown in **Fig. 1** or for single batch, or limited number of batch use, (herein also referred to as single use) such as in the centrifugal separator 2 shown in **Figs. 5a – 5d**.

The use of the herein discussed seal cartridge 14 is generally applicable to different kinds and sizes of centrifugal separators.

The present seal cartridge 14, in its simplest form provides only for the first fluid flow path 16 to communicate therethrough with the separation space 3. However, the seal cartridge 14 may provide for further fluid flow paths to communicate therethrough with the separation space 3. Such further fluid flow paths may be arranged radially outside the first fluid flow path 16, such as the exemplified second fluid flow path 18. Also the non-shown third fluid flow path may extend via the seal cartridge 14.

However, one or more further fluid flow paths, such as one or more of the second and third fluid flow paths may extend to/from the separation space 3 other than via the seal cartridge 14. Such further fluid flow paths may be open, intermittently openable, mechanically hermetically sealed, or provided with paring discs. They may be provided proximal to the seal cartridge 14, at an end portion of the centrifuge rotor 4 opposite to the seal cartridge 14 e.g. via the spindle 8, and/or at an outer periphery of the centrifuge rotor 4.

Fig. 2 schematically illustrates a section through an example of a seal cartridge 14 of a centrifugal separator 2. The seal cartridge 14 may be utilised in a centrifugal separator 2 similar to the kind discussed above with reference to **Fig. 1** or in a centrifugal separator 2 similar to the kind discussed below with reference to **Figs. 5a – 5d**. Accordingly, in the following reference is also made to the descriptions related **to Figs. 1 and 5a – 5d**.

Consequently, the seal cartridge 14 is configured for use in a centrifugal separator 2. Again, the centrifugal separator 2 comprises a stationary structure 13 and a rotatable system 9 configured to rotate about a rotational axis 6. The seal cartridge 14 is configured for sealing at least a first fluid flow path 16 extending between the stationary structure 13 and the rotatable system 9 of the centrifugal separator 2.

In **Fig. 2**, the centrifugal separator 2 with the stationary structure 13 and the rotatable system 9 is schematically indicated with broken lines.

Again, the seal cartridge 14 comprises a first sealing unit 20 and a second sealing unit 22. The first sealing unit 20 is connectable to the stationary structure 13 and the second sealing

unit 22 is connectable to the rotatable system 9. The second sealing unit 22 is rotatable about the rotational axis 6 during use of the centrifugal separator 2.

Accordingly, in the centrifugal separator 2, the first sealing unit 20 may be considered to form part of the stationary structure 13 and the second sealing unit 22 may be considered to form part of the rotatable system 9.

At least a portion of the first fluid flow path 16 extends through the first and second sealing units 20, 22. The first and second sealing units 20, 22 are arranged in sealing abutment to seal the first fluid flow path 16. Thus, the first and second sealing units 20, 22 form an interface between a portion of the first fluid flow path 16 in the stationary portion 13 of the centrifugal separator 2 and a portion of the first fluid flow path 16 in the rotatable portion 9.

The first and second sealing units 20, 22 form a mechanical hermetical seal of the first fluid flow path 16 and other fluid flow paths, as discussed below.

The first sealing unit 20 is arranged in a first casing portion 24. The first casing portion 24 is configured for being secured to the stationary structure 13, such as to the housing 12 of the centrifugal separator 2. For instance, a flange 26 of the first casing portion 24 may be configured for being clamped, screwed, or otherwise secured to the stationary portion 13.

The first sealing unit 20 is arranged in a non-rotatable manner within the first casing portion 24. For instance, a protrusion (not shown) of the first sealing portion 20 may engage with a recess (not shown) of the first sealing unit 20, or vice versa. However, the first sealing unit 20 may be axially moveable in the first casing portion 24, see further below.

The second sealing unit 22 is secured in relation to the first casing portion 24 such that the seal cartridge 14 forms one entity. Thus, as discussed herein, the seal cartridge 14 forms a single module that can be handled as such during servicing of the centrifugal separator 2 and/or replacing of the seal cartridge 14.

The second sealing unit 22 is secured to the first casing portion 24 in a manner that permits rotation of the second sealing unit 22 about the rotational axis 6. The second sealing unit 22 may be directly secured to the first casing portion 24 i.e., the first casing portion 24 engages directly with the second sealing unit 22, see also below with reference to **Fig. 4a**.

Alternatively, as in the illustrated example, the second sealing unit 22 is arranged in a second casing portion 28. In such an example, the second sealing unit 22 is secured in relation to the first casing portion 24 by the second casing portion 28 being secured in relation to the first casing portion 24. Thus, the second sealing unit 22 may be indirectly secured to the first casing portion 24.

According to some examples, such as the illustrated example, the second casing portion 28 is configured for being secured to the rotatable system 9 of the centrifugal separator 2.

For instance, the second casing portion 28 may comprise a flange 30 configured for being clamped, screwed, or otherwise secured to the rotatable portion 9.

The second sealing unit 22 is arranged in a non-rotatable manner within the second casing portion 28. In order to rotate the second sealing unit 22 about the rotational axis 6, the second casing portion 28 as secured to the rotatable system 9, provides for the second sealing unit 22 as well as the second casing portion 28 to rotate with the rotatable system 9 during use of the centrifugal separator 2. Put differently, the second sealing unit 22 and the second casing portion 28 may be considered to form part of the rotatable system 9.

According to the illustrated example, the second sealing unit 22 being secured to the first casing portion 24 in a manner that permits rotation of the second sealing unit 22 about the rotational axis 6 is provided by the first casing portion 24 comprising at least one radially protruding member 32 engaging with the second sealing unit 22 or with the second casing portion 28 to secure the second sealing unit 22 in relation to the first casing portion 24.

According to some examples, such as the illustrated example, the second casing portion 28 may comprise at least one radially protruding element 34 engaging with the first casing portion 24 to secure the second sealing unit 22 in relation to the first casing portion 24. In this manner, the securing of the second sealing unit 22 to the first casing portion 24 may be provided in a convenient manner.

For instance, the at least one radially protruding member 32 of the first casing portion 24 may be snap-fitted to the at least one radially protruding element 34 of the second casing portion 28.

For instance, the at least one radially protruding element 34 of the second casing portion 28 may comprise a flange. Thus, for instance, three or four radially protruding members 32 of

the first casing portion 24 may be snap-fitted to the at least one radially protruding element 34 comprising the flange.

In order to ensure that the first and second sealing units 20, 22 are arranged in sealing abutment to seal the first fluid flow path 16 and other fluid flow paths extending through the sealing units 20, 22, the first sealing unit 20 may be axially biased against the second sealing unit 22.

In the illustrated example, such biasing of the first sealing unit 20 against the second sealing unit 22, is enabled by resilient members 36 being arranged between the first sealing unit 20 and the first casing portion 24.

Namely, the first sealing unit 20 is moveable in an axial direction within the first casing portion 24. Moreover, the stationary structure 13 and the rotatable system 9 have specifically defined axial positions within the centrifugal separator 2. Accordingly, when the seal cartridge 14 is mounted to the stationary structure 13 and the rotatable system 9, as discussed above, the resilient members 36 are compressed between the first sealing unit 20 and the first casing portion 24. Thus, the resilient members 36 exert an axial force on the first sealing unit 20 such that it is biased against the second sealing unit 22.

In order to provide a fluid connection to, or from, the centrifugal separator 2, the seal cartridge 14 may comprise a first pipe portion 38 protruding from the first casing portion 24. A portion of the first fluid flow path 16 extends through the first pipe portion 38. Thus, the seal cartridge 14 may form an interface for at least one conduit connected to the centrifugal separator.

A conduit in the form of a flexible tubing or a rigid pipe and forming the fluid connection may be connected to the first pipe portion 38.

Figs. 3a and 3b schematically illustrate the first and second sealing units 20, 22 of the seal cartridge 14 shown in **Fig. 2**. In the following reference is made to **Figs. 2 – 3b**.

Fig. 3a shows a view of the first sealing unit 20 from a side thereof, which faces the second sealing unit 22. **Fig. 3b** shows a view of the second sealing unit 22 from a side thereof, which faces the first sealing unit 20.

The first fluid flow path 16 is indicated in both of **Figs. 3a and 3b**.

As mentioned above, the first and second sealing units 20, 22 are arranged in sealing abutment to seal the first fluid flow path 16.

According to some examples, such as the illustrated example, the first sealing unit 20 comprises a first sealing surface 40 extending around the first fluid flow path 16 and the second sealing unit 22 comprises a second sealing surface 42 extending around the first fluid flow path 16. The first and second sealing surfaces 40, 42 extend perpendicularly to the rotational axis 6. The first and second sealing units 20, 22 being arranged in sealing abutment to seal the first fluid flow path 16 is enabled by the first and second sealing surfaces 40, 42 being arranged in sealing abutment. In this manner, the first and second sealing units 20, 22 form a mechanical hermetical seal of the first fluid flow path 16.

The first fluid flow path 16 extends concentrically with the rotational axis 6. The portion of the first fluid flow path 16 that extends through the first and second sealing units 20, 22 is formed by through holes in the first and second sealing units 20, 22.

In the illustrated example, the second sealing surface 42 is indicated between broken lines in **Fig. 3b**. The first sealing surface 40 is formed between the first fluid flow path 16 and a first circumferential channel 44 in the axial face of the first sealing unit 20 facing the second sealing unit 22. The first circumferential channel 44 extends at a radial distance from the first fluid flow path 16.

As discussed above, the seal cartridge 14 may be configured for sealing further fluid flow paths, such as a second fluid flow path 18 and a third fluid flow path 46. The seal cartridge 14 discussed in connection with **Fig. 1** seals a first and a second fluid flow path 16, 18. The seal cartridge 14 discussed in connection with **Figs. 2- 3b** seals a first, a second, and a third fluid flow path 16, 18, 46. The seal cartridge 14 discussed below with reference to **Figs. 4a – 4c** seals only a first fluid flow path 16.

According to some examples, such as the illustrated example, the seal cartridge 14 is configured for sealing a second fluid flow path 18 extending between the stationary structure 13 and the rotatable system 9 of the centrifugal separator 2. At least a portion of the second fluid flow path 18 extends through the first and second sealing units 20, 22. The first sealing unit 20 comprises a third sealing surface 48 extending around the first sealing surface 40 and the second sealing unit 22 comprises a fourth sealing surface 50 extending around the second sealing surface 42. The third and fourth sealing surfaces 48, 50 extend

perpendicularly to the rotational axis 6. The second fluid flow path 18 extends between the first and second sealing units 20, 22 at a radial position between the first and third sealing surfaces 40, 48. The first and second sealing surfaces 40, 42 are arranged in sealing abutment as well as the third and fourth sealing surfaces 48, 50 are arranged in sealing abutment to seal the second fluid flow path 18. In this manner, the first and second sealing units 20, 22 form a mechanical hermetical seal of the second fluid flow path 18.

In the illustrated example, the fourth sealing surface 50 is indicated between broken lines in **Fig. 3b**. The third sealing surface 40 is formed between the first circumferential channel 44 and a second circumferential channel 52 in the axial face of the first sealing unit 20 facing the second sealing unit 22.

According to some examples, such as the illustrated example, the first and third sealing surfaces 40, 48 extend in one radial plane. In this manner, one or both of the first and second sealing units 20, 22 may be easily polished to provide durable mechanical hermetical seals of the first and second fluid flow paths 16, 18.

According to some examples, such as the illustrated example, the seal cartridge 14 is configured for sealing a third fluid flow path 46 extending between the stationary structure 13 and the rotatable system 9 of the centrifugal separator 2. At least a portion of the third fluid flow path 46 extends through the first and second sealing units 20, 22. The first sealing unit 20 comprises a fifth sealing surface 54 extending around the third sealing surface 48 and the second sealing unit 22 comprises a sixth sealing surface 56 extending around the fourth sealing surface 50, the fifth and sixth sealing surfaces 54, 56 extending perpendicularly to the rotational axis 6. The third fluid flow path 46 extends between the first and second sealing units 20, 22 at a radial position between the third and fifth sealing surfaces 48, 54. The third and fourth sealing surfaces 48, 50 are arranged in sealing abutment as well as the fifth and sixth sealing surfaces 54, 56 are arranged in sealing abutment to seal the third fluid flow path 46. In this manner, the first and second sealing units 20, 22 form a mechanical hermetical seal of the third fluid flow path 46.

In the illustrated example, the sixth sealing surface 56 is indicated between broken lines in **Fig. 3b**. The fifth sealing surface 54 is formed between the second circumferential channel 52 and an outer periphery of the first sealing unit 20 in the axial face of the first sealing unit 20 facing the second sealing unit 22.

The portion of the second fluid flow path 18 extending through the first and second sealing units 20, 22 is partially formed by through holes in each of the first and second sealing units 20, 22. The first circumferential channel 44 forms part of the second fluid flow path 18. The first circumferential channel 44 enables fluid flow along the second fluid flow path 18 while the second sealing unit 22 rotates with the rotatable system 9 of the centrifugal separator 2. Namely, during use of the centrifugal separator 2, as the rotatable system 9 rotates, the through hole of the second fluid flow path 18 that extends through the second sealing unit 22 rotates in a circle having the same radius as the first circumferential channel 44 and thus, will always be arranged in fluid communication with the first circumferential channel 44. The through hole of the second fluid flow path 18 that extends through the first sealing unit 20 is arranged in fluid communication with the first circumferential channel 44 within the first sealing unit 20.

Similarly, the portion of the third fluid flow path 46 extending through the first and second sealing units 20, 22 is partially formed by through holes in each of the first and second sealing units 20, 22. The second circumferential channel 52 forms part of the third fluid flow path 46. The second circumferential channel 52 enables fluid flow along the third fluid flow path 46 while the second sealing unit 22 rotates with the rotatable system 9 of the centrifugal separator 2. During use of the centrifugal separator 2, as the rotatable system 9 rotates, the through hole of the third fluid flow path 46 that extends through the second sealing unit 22 rotates in a circle having the same radius as the second circumferential channel 52 and thus, will always be arranged in fluid communication with the second circumferential channel 52. The through hole of the third fluid flow path 46 that extends through the first sealing unit 20 is arranged in fluid communication with the second circumferential channel 52 within the first sealing unit 20.

Alternatively, or additionally, to the first and second circumferential channels 44, 52, the second sealing unit 22 in its face facing the first sealing unit 20 may be provided with circumferential channels corresponding to the first and second circumferential channels 44, 52. Such circumferential channels in the second sealing unit 22 would be arranged between the second and fourth sealing surfaces 42, 50 and between the fourth and sixth sealing surfaces 50, 56.

According to some examples, such as the illustrated example, see **Fig. 2**, the seal cartridge 14 comprises a second pipe portion 58 protruding from the first casing portion 24. A portion of the second fluid flow path 18 extends through the second pipe portion 58. In this manner,

a second conduit may be connected to the seal cartridge 14 for conduction a fluid therethrough.

Thus, the seal cartridge 14 may form an interface for a second conduit connected to the centrifugal separator 2. For instance, a conduit in the form of a flexible tubing or a rigid pipe may be connected to the second pipe portion 58.

According to some examples, such as the illustrated example, the seal cartridge 14 comprises a third pipe portion 60 protruding from the first casing portion 24. A portion of the third fluid flow path 46 extends through the third pipe portion 60. In this manner, a third conduit may be connected to the seal cartridge 14 for conduction a fluid therethrough.

Thus, the seal cartridge 14 may form an interface for a third conduit connected to the centrifugal separator 2. For instance, a conduit in the form of a flexible tubing or a rigid pipe may be connected to the third pipe portion 60.

Instead of one or more of the first, second, and third pipe portions 38, 58, 60, the first casing portion 24 may be to provide one or more threaded openings and/or a bayonet couplings in connection with the respective first, second, and third fluid flow paths 16, 18, 46. Flexible tubing or a ridged pipes may be connected to such threaded openings and/or the bayonet couplings.

In the shown example, the second and third fluid flow paths 18, 46 include only one passage through the first sealing unit 20 and the first casing portion 24. Alternatively, the second and/or third fluid flow paths 18, 46 may include more than one, such as two passages through the first sealing unit 20 and/or the first casing portion 24 to, or from, the first and/or second circumferential channels 44, 52.

In the example of **Figs. 2 – 3b**, it is proposed that a fluid feed mixture is supplied through the first fluid flow path 16 via a conduit connected to the first pipe section 38 to the separation space in the rotatable system 9. The separated light phase is lead from the separation space through the second fluid flow path 18 via a conduit connected to the second pipe portion 58. The separated heavy phase is lead from the separation space through the third fluid flow path 46 via a conduit connected to the third pipe portion 60. Alternatively, the first, second, and third fluid flow paths 16, 18, 46 may be used in other constellations for the fluids to flow therethrough.

Figs. 4a – 4c schematically illustrate an example of a seal cartridge 14 for a centrifugal separator. **Fig. 4a** schematically illustrates a section through the seal cartridge 14 along a rotational axis 6. **Figs. 4b and 4c** illustrate first and second sealing units 20, 22 of the seal cartridge 14. **Fig. 4b** shows a view of the first sealing unit 20 from a side thereof, which faces the second sealing unit 22. **Fig. 4c** shows a view of the second sealing unit 22 from a side thereof, which faces the first sealing unit 20.

The seal cartridge 14 of the **Figs. 4a – 4c** example resembles in much the seal cartridge 14 of the **Fig. 2 – 3b** example. Accordingly, reference is also made to the above discussion of the **Fig. 2 – 3b** example. In the following mainly, the differences between the examples will be discussed.

Again, at least a portion of a first fluid flow path 16 extends through the first and second sealing units 20, 22. The first and second sealing units 20, 22 are arranged in sealing abutment to seal the first fluid flow path 16. The first sealing unit 20 is arranged in a first casing portion 24.

In this example, the second sealing unit 22 is directly secured in relation to the first casing portion 24. Again, the seal cartridge 14 forms one entity that can be handled as a single module.

Again, the second sealing unit 22 is secured to the first casing portion 24 in a manner that permits rotation of the second sealing unit 22 about the rotational axis 6.

For instance, at least one radially protruding member 32 of the first casing portion 24 may be snap-fitted to a flange 61 of the second sealing unit 22.

The second sealing unit 22 is configured to be secured to the rotatable system of a relevant centrifugal separator. For instance, the second sealing unit 22 and a thereto adjacent portion of the rotatable system may be provided with mating protrusions and recesses (not shown), which ensure that the second sealing unit 22 is rotatably locked to the rotatable system. In an axial direction, the second sealing unit 22 may be secured by the first casing portion 24 being secured to the stationary structure of the centrifugal separator.

Again, the first sealing unit 22 is axially biased against the second sealing unit 22 to ensure that the first and second sealing units 20, 22 are arranged in sealing abutment to seal the first fluid flow path 16 and other fluid flow paths extending through the sealing units 20, 22.

Again, at least one resilient member 36 arranged between the first sealing unit 20 and the first casing portion 24 provides such biasing. Since **Fig. 4a** shows the seal cartridge 14 in an unmounted state e.g., before being mounted in a centrifugal separator, the at least one resilient member 36 biases the first and second sealing units 20, 22 fully in an axial direction. The flange 61 of the second sealing unit 22 abutting against the at least one radially protruding member 32 of the first casing portion 24 prevents at least the second sealing unit 22 from being separated from the seal cartridge 14.

When mounted in a centrifugal separator, the second sealing unit 22 has been axially displace against the biasing force provided by the at least one resilient member 36 such that the flange 61 of the second sealing unit 22 does not abut against the at least one radially protruding member 32 of the first casing portion 24. This position of the second sealing unit 22 in the seal cartridge 14 is shown in **Fig. 6b** and in a corresponding manner in **Fig. 2**.

According to some examples, such as in the example of **Figs. 4a – 4c**, the seal cartridge 14 is provided with a cooling fluid flow path 70 extending through the first sealing unit 20 to a surface of the second sealing unit 22. The first sealing unit 20 and/or the second sealing unit 22 are/is provided with a cooling fluid groove 72 extending circumferentially around the rotational axis 6 and forming part of the cooling fluid flow path 70. The first and second sealing units 20, 22 are provided with circumferentially extending cooling fluid sealing surfaces 74 arranged radially inside and outside the cooling fluid groove 72. In this manner, during use of the centrifugal separator, a cooling fluid may be supplied to surfaces of the first and second sealing units 20, 22. Thus, the seal cartridge 14 may be cooled with a dedicated cooling fluid during use of the seal cartridge 14 in a centrifugal separator.

In the example of **Figs. 4a – 4c**, the cooling fluid flow path 70 extends through the seal cartridge 14 via a first pipe stub 76, through the first sealing unit 20, the cooling fluid groove 72 along the second sealing unit 22, and via the first sealing unit 20 and a second pipe stub 78.

In the example of **Figs. 4a – 4c**, the first and second sealing surfaces 40, 42 have a double function since they also form the radially inner cooling fluid sealing surfaces 74.

Accordingly, one or more abutting pairs of the first – sixth sealing surfaces 40, 42, 48, 50, 54, 56 discussed above with reference to the example of **Figs. 2 – 3b** may form cooling fluid sealing surfaces in addition to forming sealing surfaces of one or more of the first – third fluid

flow paths 16, 18, 46 in embodiments of the seal cartridge 14 comprising more than one fluid flow path extending through the first and second sealing units 20, 22. Alternatively, dedicated cooling fluid sealing surfaces 74 may be provided.

In the example of **Figs. 4a – 4c**, the cooling fluid groove 72 is provided in the first sealing unit 20 only. However, additionally or alternatively, the cooling fluid groove 72 may be provided in the second sealing unit 22.

More than one cooling fluid groove extending circumferentially around the rotational axis 6 may be provided. Such more than one cooling fluid groves may form part of the cooling fluid flow path 70 or of one or more separate cooling fluid flow paths.

Figs. 5a – 5d schematically illustrate an example of a centrifugal separator 2. The centrifugal separator 2 is configured for separating a liquid feed mixture into a heavy phase and light phase. The centrifugal separator 2 may be configured for use in the field of pharmaceuticals, biopharmaceuticals, and/or biotechnology. For instance, the centrifugal separator 2 may form part of a set-up in a plant for the production of cells such as, CHO cells (Chinese Hamster Ovary cells), or other matter resulting from processes in the biotech/pharma industry.

Again, the centrifugal separator 2 comprises a stationary structure 13, a rotatable system 9 configured to rotate about a rotational axis 6, and a seal cartridge 14 configured for sealing at least a first fluid flow path 16 extending between the stationary structure 13 and the rotatable system 9.

The seal cartridge 14 is one according to aspects and/or examples discussed herein, such as the seal cartridge 14 discussed in the example of **Figs. 2 – 3b**.

The centrifugal separator 2 is configured for single batch use, or limited number of batch use. As such the centrifugal separator 2 comprises single use parts including inter alia an exchangeable separation insert 62, and an exchangeable seal cartridge 14, which may form part of an exchangeable tube kit 64. In **Fig 5a**, the centrifugal separator 2 is shown in an assembled state i.e., with the separation insert 62, the seal cartridge 14, and the tube kit 8 mounted in the portions of the centrifugal separator 2, which portions are configured for multiple use. In **Fig 5b**, the exchangeable separation insert 62 is shown. In **Fig. 5c**, the seal cartridge 14 and the exchangeable tube kit 64 are shown. In **Fig 5d**, the separation insert 62 and the tube kit 64 including the seal cartridge 14 are shown adjacent to each other in a manner, in which they are arranged when mounted in the centrifugal separator 2.

Portions of the centrifugal separator 2 which are configured for multiple use are known and are briefly discussed in the example of **Figs. 6a and 6b**. For instance, centrifugal separator portions configured for multiple use are describes as part of a base unit in the above-mentioned document, WO 2022/233539.

The centrifugal separator 2 is modular in the sense that it inter alia comprises portions configured for multiple use and portions configured for single use, including the exchangeable separation insert 62 and the exchangeable tube kit 64 with the seal cartridge 14.

The exchangeable separation insert 62 and the exchangeable tube kit 64 may be exchanged for each new batch of fluid feed mixture, which is to be separated. Alternatively, the exchangeable separation insert 62 and the exchangeable tube kit 64 may be exchanged for each new type of fluid feed mixture, which is to be separated, i.e. one or more subsequent batches containing same type of liquid feed mixtures may be separated utilising the same separation insert 62 and the tube kit 64.

During use of the centrifugal separator 2, only the fluid feed mixture and the separated light and heavy phases come into contact with exchangeable portions, such as with the insides of the separation insert 62 and the tube kit 64. The portions of the centrifugal separator 2 configured for multiple use do not come into contact with the fluid feed mixture or any of the light and heavy phases.

The exchangeable separation insert 62 and the seal cartridge 14, e.g. included in the exchangeable tube kit 64 together with one or more tubes, may be provided separately to a user of the centrifugal separator 2. That is, the separation insert 62 as shown in **Fig. 5b** and the tube kit 64 as shown in **Fig. 5c** may be offered to a user as unassembled separate parts, which thus, are provided for mounting in the centrifugal separator 2 one at a time.

The separation insert 62 comprises a rotor casing 66 forming therein a separation space. The rotor casing 66 is configured to be rotated about the rotational axis 6. Accordingly, in the centrifugal separator 2, the rotor casing 66 forms part of the rotatable system 9 of the centrifugal separator 2.

The exchangeable tube kit 64 comprises at least one tube for one of the fluid feed mixture, the heavy phase, and the light phase.

In the illustrated example, the tube kit 64 comprises all fluid connections for conducting fluid to and from the centrifugal separator 2. That is, the tube kit 64 comprises tubes forming part of the first fluid flow path 16, a second fluid flow path 18, and a third fluid flow path 46 i.e., for the liquid feed mixture, the separated heavy phase, and the separated light phase.

Accordingly, also the seal cartridge 14 provides for at least a portion of the first fluid flow path 16 to extend therethrough. In the illustrated example, the seal cartridge 14 provides for all fluid connections for conducting fluid/liquid to and from the centrifugal separator 2 to extend through therethrough. That is, the seal cartridge 14 further provides for a portion of the second fluid flow path 18, and for a portion of the third fluid flow path 46 to extend therethrough.

The seal cartridge 14 may be cooled by a cooling fluid during use of the centrifugal separator 2. In such case, the seal cartridge 14 is provided with connections for the cooling fluid. An example of this is discussed above with reference to **Figs. 4a – 4c**.

In the example of **Figs. 5a – 5d**, as shown in **Fig. 5d**, in use of the centrifugal separator 2, the seal cartridge 14 is arranged above the separation insert 62.

According to alternative examples, the centrifugal separator 2 and the separation insert 62 may be configured for arranging the seal cartridge 14 below the separation insert 62 during use of the centrifugal separator 2.

According to further alternative examples, the centrifugal separator 2 may comprise a further seal cartridge. In such embodiments, one seal cartridge is arranged at each end of the separation insert 62, which is configured for connection to the two seal cartridges.

A removable sealing strip 80 may be provided for covering openings in the seal cartridge 14 and/or in the exchangeable separation insert 62. In **Fig. 5b**, a removable sealing strip 80 is shown covering one or more openings of the separation insert 62. Also, openings in the seal cartridge 14, such as openings of the first – third fluid flow paths 16, 18, 46 in the second sealing unit of the seal cartridge 14, may be covered by a removable sealing strip 80 (partially shown). Accordingly, the removable sealing strip 80 may comprise two portions, one portion covering portions of each of the seal cartridge 14 and the separation insert 62.

The removable sealing strip 80 is removed in connection with installation of the separation insert 62 and the seal cartridge 14 in the centrifugal separator 2.

Figs. 6a and 6b schematically illustrate sections through portions of a centrifugal separator 2.

Again, the centrifugal separator 2 comprises a stationary structure 13 and a rotatable system 9 configured to rotate about a rotational axis 6 and a seal cartridge 14 configured for sealing at least a first fluid flow path 16 extending between the stationary structure 13 and the rotatable system 9 of the centrifugal separator 2.

The rotatable system 9 comprises an exchangeable separation insert 62 mounted in a rotatable member 82 configured for multiple use. The rotatable member 82 and the separation insert 62 form part of a centrifuge rotor 4 of the rotatable system 9.

The seal cartridge 14 is exchangeable and is mounted in the centrifugal separator 2. The seal cartridge 14 may form part of a tube kit 64.

Accordingly, the rotatable system 9 comprises an exchangeable separation insert 62, wherein the separation space 3 is delimited by the exchangeable separation insert 62, and wherein the second sealing unit 22 of the seal cartridge 14 is connected to the exchangeable separation insert 62.

The seal cartridge 14 may be a seal cartridge according to any one of the aspects and examples discussed herein. In **Fig. 6a** the seal cartridge 14 is indicated. In **Fig. 6b**, the seal cartridge 14 is shown in more detail and exemplified in the form of the seal cartridge 14 discussed in connection with **Figs. 4a – 4c**.

Further fluid flow paths extending between the rotatable system 9 and the stationary structure 13 are arranged at an end of the exchangeable separation insert 62 opposite to the seal cartridge 14.

Mentioned purely as an example of assembling the centrifugal separator 2:
- A lid 84 of the stationary structure 13 is opened and a cap 86 of the rotatable member 82 is removed.
- The separation insert 62 is placed inside the rotatable member 82.
- The cap 86 is repositioned at the rotatable member 82.

- The seal cartridge 14 is arranged such that a second sealing unit 22 thereof engages directly or indirectly with the separation insert 62.
- The lid 84 is closed. In doing so, a first sealing unit 20 of the seal cartridge 14 is correctly positioned for use in the centrifugal separator 2. The lid 84 may for this purpose engage with a flange 26 of a first casing portion 24.

With reference to **Figs. 1 – 6b**, according to some examples, the first fluid flow path 16 forms an inlet for a fluid feed mixture to be separated in the separation space 3 or an outlet for a phase separated in the separation space 3.

In the examples of **Figs. 1 – 3b**, the first fluid flow path 16 forms an inlet for a fluid feed mixture. In the examples of **Figs. 6a and 6b**, the first fluid flow path 16 forms an outlet for a phase separated in the separation space 3.

According to some examples, such as the illustrated examples, in the centrifugal separator 2, the seal cartridge 14 forms an only seal, between the stationary structure 13 and the rotatable system 9 of the centrifugal separator 2 for a fluid feed mixture supplied to the separation space 3, and/or for a separated light phase led from the separation space 3, and/or for a liquid heavy phase led from the separation space 3.

The terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. It will be further understood that the terms "comprises," "comprising," "includes," and/or "including" when used herein specify the presence of stated features, integers, actions, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, actions, steps, operations, elements, components, and/or groups thereof.

It will be understood that, although the terms first, second, etc., may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element without departing from the scope of the present disclosure.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms used herein should be interpreted as having a meaning consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

It is to be understood that the foregoing is illustrative of various examples and that the invention is defined only by the appended claims. A person skilled in the art will realize that the examples may be modified, and that different features of the examples may be combined to create examples other than those described herein, without departing from the scope of the invention, as defined by the appended claims.

CLAIMS

1. A seal cartridge (14) for a centrifugal separator (2), the centrifugal separator (2) comprising a stationary structure (13) and a rotatable system (9) configured to rotate about a rotational axis (6), the seal cartridge (14) being configured for sealing at least a first fluid flow path (16) extending between the stationary structure (13) and the rotatable system (9) of the centrifugal separator (2), wherein

the seal cartridge (14) comprises a first sealing unit (20) and a second sealing unit (22), wherein

the first sealing unit (20) is connectable to the stationary structure (13) of the centrifugal separator (2), wherein

the second sealing unit (22) is connectable to the rotatable system (9) of the centrifugal separator (2) and rotatable about the rotational axis (6) during operation of the centrifugal separator (2), wherein

at least a portion of the first fluid flow path (16) extends through the first and second sealing units (20, 22) and the first and second sealing units (20, 22) are arranged in sealing abutment to seal the first fluid flow path (16), wherein

the first sealing unit (20) is arranged in a first casing portion (24), and wherein

the second sealing unit (22) is secured in relation to the first casing portion (24) such that the seal cartridge (14) forms one entity.

2. The seal cartridge (14) according to claim 1, wherein the second sealing unit (22) is arranged in a second casing portion (28), and wherein the second sealing unit (22) is secured in relation to the first casing portion (24) by the second casing portion (28) being secured in relation to the first casing portion (24).

3. The seal cartridge (14) according to claim 2, wherein the second casing portion (28) is configured for being secured to the rotatable system (9) of the centrifugal separator (2).

4. The seal cartridge (14) according to any one of the preceding claims, wherein the first casing portion (24) comprises at least one radially protruding member (32) engaging with the second sealing unit (22) or with the second casing portion (28) to secure the second sealing unit (22) in relation to the first casing portion (24).

5. The seal cartridge (14) according to any one of claims 2 - 4, wherein the second casing portion (28) comprises at least one radially protruding element (34) engaging with the first

casing portion (24) to secure the second sealing unit (22) in relation to the first casing portion (24).

6. The seal cartridge (14) according to any one of the preceding claims, wherein the first sealing unit (20) is axially biased against the second sealing unit (22).

7. The seal cartridge (14) according to any one of the preceding claims, wherein the first sealing unit (20) comprises a first sealing surface (40) extending around the first fluid flow path (16) and the second sealing unit (22) comprises a second sealing surface (42) extending around the first fluid flow path (16), the first and second sealing surfaces (40, 42) extending perpendicularly to the rotational axis (6), and wherein

the first and second sealing units (20, 22) being arranged in sealing abutment to seal the first fluid flow path (16) is enabled by the first and second sealing surfaces (40, 42) being arranged in sealing abutment.

8. The seal cartridge (14) according to any one of the preceding claims, being configured for sealing a second fluid flow path (18) extending between the stationary structure (13) and the rotatable system (9) of the centrifugal separator (2), wherein

at least a portion of the second fluid flow path (18) extends through the first and second sealing units (20, 22), wherein

the first sealing unit (20) comprises a third sealing surface (48) extending around the first sealing surface (40) and the second sealing unit (22) comprises a fourth sealing surface (50) extending around the second sealing surface (42), the third and fourth sealing surfaces (48, 50) extending perpendicularly to the rotational axis (6), wherein

the second fluid flow path (18) extends between the first and second sealing units (20, 22) at a radial position between the first and third sealing surfaces (40, 48), and wherein

the first and second sealing surfaces (40, 42) are arranged in sealing abutment as well as the third and fourth sealing surfaces (48, 50) are arranged in sealing abutment to seal the second fluid flow path (18).

9. The seal cartridge (14) according to claim 8, wherein the first and third sealing surfaces (40, 48) extend in one radial plane.

10. The seal cartridge (14) according to claim 8 or 9, being configured for sealing a third fluid flow path (46) extending between the stationary structure (13) and the rotatable system (9) of the centrifugal separator (2), wherein

at least a portion of the third fluid flow path (46) extends through the first and second sealing units (20, 22), wherein

the first sealing unit (20) comprises a fifth sealing surface (54) extending around the third sealing surface (48) and the second sealing unit (22) comprises a sixth sealing surface (56) extending around the fourth sealing surface (50), the fifth and sixth sealing surfaces (54, 56) extending perpendicularly to the rotational axis (6), wherein

the third fluid flow path (46) extends between the first and second sealing units (20, 22) at a radial position between the third and fifth sealing surfaces (48, 54), and wherein

the third and fourth sealing surfaces (48, 50) are arranged in sealing abutment as well as the fifth and sixth sealing surfaces (54, 56) are arranged in sealing abutment to seal the third fluid flow path (46).

11. The seal cartridge (14) according to any one of the preceding claims, being provided with a cooling fluid flow path (70) extending through the first sealing unit (20) to a surface of the second sealing unit (22), wherein

the first sealing unit (20) and/or the second sealing unit (22) are/is provided with a cooling fluid groove (72) extending circumferentially round the rotational axis (6) and forming part of the cooling fluid flow path (70), and wherein

the first and second sealing units (20, 22) are provided with circumferentially extending cooling fluid sealing surfaces (74) arranged radially inside and outside the cooling fluid groove (72).

12. A centrifugal separator (2) comprising a stationary structure (13) and a rotatable system (9) delimiting a separation space (3), wherein a first fluid flow path (16) is arranged in fluid communication with the separation space (3), wherein the centrifugal separator (2) comprises a seal cartridge (14) according to any one of the preceding claims, wherein the first casing portion (24) of the seal cartridge (14) is connected to the stationary structure (13), and wherein the second sealing unit (22) of the seal cartridge (14) is connected to the rotatable system (9).

13. The centrifugal separator (2) according to claim 12, wherein the rotatable system (9) comprises an exchangeable separation insert (62), wherein the separation space (3) is delimited by the exchangeable separation insert (62), and wherein the second sealing unit (22) of the seal cartridge (14) is connected to the exchangeable separation insert (62).

14. The centrifugal separator (2) according to claim 12 or 13, wherein the first fluid flow path (16) forms an inlet for a fluid feed mixture to be separated in the separation space (3) or an outlet for a liquid phase separated in the separation space (3).

15. The centrifugal separator (2) according to any one of claims 12 - 14, wherein the seal cartridge (14) forms an only seal, between the stationary structure (13) and the rotatable system (9) of the centrifugal separator (2) for a fluid feed mixture supplied to the separation space (3), and/or for a separated light phase led from the separation space (3), and/or for a separated heavy phase led from the separation space (3).