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(54) **Title:** SEAL FOR A GAS INSULATED HIGH OR MEDIUM VOLTAGE DEVICE

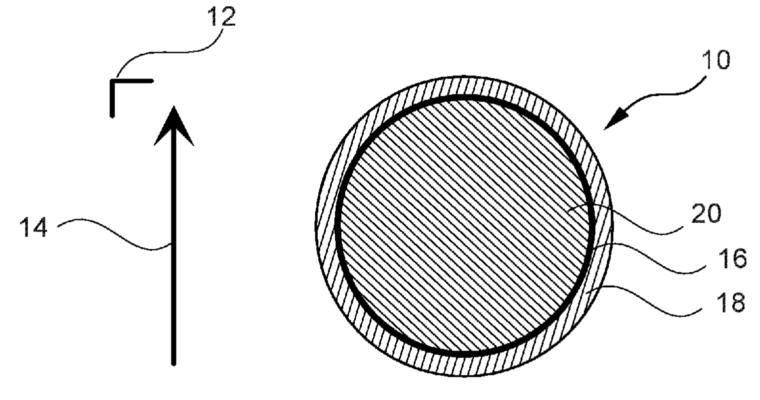

Fig. 1

(57) **Abstract:** The invention relates to a seal (10) for a gas insulated high or medium voltage device, the seal (10) having a toroid shape and comprising a permeation barrier (16) consisting of a first material, and a contact layer (18) consisting of a second material, wherein an outer surface of the seal (10) is at least partially formed by the contact layer (18), wherein the first material comprises EVOH, Al_2O_3, Aluminum and/or mixtures thereof, and wherein the second material comprises silicone rubber, PE, IIR and/or mixtures thereof. Furthermore, the invention relates to a gas-insulated high or medium voltage device comprising the above seal (10) and an insulation gas. Furthermore, the invention relates to the use of the above seal (10) for sealing a gas insulated high or medium voltage devices, against a loss of an insulation gas. Further, the invention relates to methods for producing the above seal (10).

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Description

Seal for a gas insulated high or medium voltage device

Technical Field

The invention relates to a seal for a gas insulated high or medium voltage device.

Furthermore, the invention relates to a gas-insulated high or medium voltage device comprising the above seal.

Furthermore, the invention relates to the use of the above seal for sealing a gas insulated high or medium voltage devices, against a loss of an insulation gas.

Further, the invention relates to methods for producing the above seal.

Background Art

High or medium voltage devices, such as circuit breakers and switchgears are essential for the protection of technical equipment, especially in the high voltage range. For example, circuit breakers are predominantly used for interrupting a current, when an electrical fault occurs. As an example, circuit breakers have the task of opening arcing contacts, quench an arc, and keeping the arcing contacts apart from one another in order to avoid a current flow even in case of high electrical potential originating from the electrical fault itself. Circuit breakers may break medium to high short circuit currents of typically 1 kA to 80 kA at medium to high voltages of 12 kV to 72 kV and up to 1200 kV. Thus, high or medium voltage devices accommodate high-voltage conductors such as conductors to which a high voltage is applied.

Some high or medium voltage devices, namely gas-insulated high or medium voltage devices comprise an insulation gas, for example sulphur hexafluoride. For circuit breakers the insulation gas has for example the task to shield and insulate the high-voltage conductor from other component and/or to improve quenching of an arc, when operating arcing contacts inside the arcing chamber.

Sulphur hexafluoride (SF_6) is widely used as insulation gas, as it is known for its high dielectric strength and thermal interruption capability. However, SF_6 might have some environmental impact when released into the atmosphere, in particular due to its relatively high global warming potential and its relatively long lifetime in the atmosphere.

Sealing systems such as seals or gaskets have been developed in order to prevent the escape of the insulation gas and to prevent the intrusion of impurities into the high or medium voltage device, which could affect the dielectric performance of the insulation gas. Seals used for gas insulated high or medium voltage devices for example need to assure that the maximum gas loss is below a certain threshold for example below 0.5% per year.

Furthermore, efforts have been made to substitute SF_6 with different more environmentally friendly insulation gases or to reduce the SF_6 content in the insulation gas mixture. For example, one candidate for substituting SF_6 as insulation gas is CO_2. However, the efforts to substitute SF_6 or to reduce its content in the insulation gas mixture has also consequences for the sealing system as for example, the permeation of CO_2 is much higher than that of SF_6. Therefore, there is a need to lower the permeation rates of the insulation gas of high or medium voltage devices.

Summary of invention

It is an object of the invention to provide means to improve the environmentally friendliness, the reliability and the lifetime of gas insulated high or medium voltage devices. It is further an object of the present invention to decrease the leakage of insulation gas in gas insulated high or medium voltage devices.

The object of the invention is solved by the features of the independent claims. Modified embodiments are detailed in the dependent claims.

Thus, the object is solved by a seal for a gas insulated high or medium voltage device, the seal having a toroid shape and comprising a permeation barrier consisting of a first material, and a contact layer consisting of a second material, wherein an outer surface of the seal is at least partially formed by the contact layer, wherein the first material comprises EVOH, Al_2O_3, Aluminum and/or mixtures thereof, and wherein the second material comprises silicone rubber, PE, IIR and/or mixtures thereof.

The object is also solved by a gas insulated high or medium voltage device comprising the above seal and an insulation gas.

Furthermore, the object is solved by the use of the above seal for sealing a gas insulated high or medium voltage devices, against a loss of an insulation gas of the high or medium voltage device.

Preferably the gas insulated high or medium voltage device is configured as a gas insulated switchgear, a live tank breaker, a dead tank breaker, a circuit breaker, a voltage instrument transformer, a current instrument transformer, a gas-insulated transmission line, a bushing and/or a mixed technology switchgear. Furthermore, in the context of this invention medium to high voltages means voltages of 12 kV to 72 kV (medium voltage) and up to 1200 kV (high voltage).

With regard to the insulation gas, the insulation gas is preferably selected from the group consisting of SF_6, dry air, CO_2, mixtures comprising CO_2, mixtures comprising fluoroketones, mixtures comprising fluoronitriles, mixtures of CO_2 with a carrier gas, mixtures of fluoroketones and/or fluoronitriles with a carrier gas, mixtures consisting of N_2 and O_2, mixtures consisting of CO_2 and O_2, mixtures consisting of fluoroketones, N_2 and O_2, mixtures consisting of fluoronitriles, N_2 and O_2, mixtures consisting of fluoroketones, CO_2 and O_2, mixtures consisting of fluoronitriles, CO_2 and O_2.

The carrier gas for use with CO_2, fluoroketones and/or fluoronitriles may comprise dry air, N_2, O_2, CO_2, and mixtures thereof. Further preferably the insulation gas may have a reduced fluorine content compared to SF_6 or may even be fluorine free.

A preferred fluoroketone is $CF_3C(O)CF(CF_3)_2$. $CF_3C(O)CF(CF_3)_2$ is preferably used with CO_2, N_2, CO_2/O_2 mixtures, and/or with N_2/O_2 mixtures. A preferred fluoronitrile is *iso*-C_3F_7CN. *iso*-C_3F_7CN is preferably used with CO_2, N_2, CO_2/O_2 mixtures, and/or with N_2/O_2 mixtures.

Particularly preferred the insulation gas is selected from the group consisting of dry air, mixtures comprising fluoroketones, mixtures comprising fluoronitriles, mixtures consisting of N_2 and O_2, mixtures consisting of CO_2 and O_2, mixtures consisting of fluoroketones, N_2 and O_2, mixtures consisting of fluoronitriles, N_2 and O_2, mixtures consisting of fluoroketones, CO_2 and O_2, mixtures consisting of fluoronitriles, CO_2 and O_2. The ratio of N_2 to O_2 in the N_2/O_2 mixture is preferably from 90 Vol% (N_2) / 10 Vol% (O_2) to 80 Vol% (N_2) / 20 Vol% (O_2), for example 90 Vol% to 10 Vol%, 85 Vol% to 15 Vol%, or 80 Vol% to 20 Vol%.

With regard to the high or medium voltage device comprising the seal, the seal is preferably arranged on an insulator spacer of the high or medium voltage device. Preferably the insulator spacer is part of an insulator of the high or medium voltage device. The insulator preferably comprising the insulator spacer and a metal insert. The insulator can be configured as a disc type insulator. Alternatively, the insulator can be configured as a conical type insulator – also called basin type insulator. Preferably, the insulator enables that a conductor of the high or medium voltage device is firmly located inside the high or medium voltage device, in a position sufficiently far away from a grounded enclosure of the high or medium voltage device. The metal insert of the insulator is preferably configured to provide electrical connection to the conductor of the high or medium voltage device. Furthermore, the volume enclosed by the enclosure of the high or medium voltage device may be divided in several compartments by the insulator. Further preferably the insulator is configured to keep a required pressure between compartments of the gas insulated high or medium voltage device and to avoid insulation gas leakage to the environment.

The insulator spacer preferably comprises a sealing groove, preferably for sealing a connection of the insulator spacer with an enclosure of the gas insulated high or medium voltage device. Further preferably the seal is arranged in the sealing groove of the insulator spacer. The insulator spacer preferably has flat shape with a first face and a second face, wherein the first face and second face are opposite to each other. Further preferably the first face and second face are connected to each other by at least one lateral face. Preferably, the sealing groove is not arranged within the lateral face. Instead, the sealing groove is preferably arranged in the first and/or second face. Further preferably the first face and the second face of the insulator spacer each comprise a sealing groove.

Furthermore, the insulator spacer preferably has a circular form, and the sealing groove extends circumferentially along a rim of the insulator spacer. More preferably the sealing groove extends circumferentially on the first and/or second face of the insulator spacer along an outer rim of the insulator spacer, and even more preferably the sealing groove extends circumferentially along the edge of the first and/or second face to the lateral face on the first and/or second face of the insulator spacer. The insulator spacer is preferably attached to a housing which is part of the grounded enclosure of the high or medium voltage device by a flange. The seal is preferably used to seal the connection of the insulation spacer to the housing. Further preferably the seal is configured as gasket.

With regard to the seal, it has been found that providing a seal comprising a permeation barrier consisting of the first material enhances the tightness of the gas insulated high or medium voltage device. As the outer surface of the seal is at least partially formed by the contact layer, and preferably solely formed by the contact layer, or in other words, as the permeation barrier is embedded within the seal, there is no need to redesign the high or medium voltage device. In particular when using the seal for sealing a high or medium voltage device, the first material is preferably not in direct contact to the high or medium voltage device. Thus, compatibility issues are avoided.

The permeation barrier of the seal preferably has a thickness of at least 1 μm, more preferably of at least 3 μm, and even more preferably at least 5 μm. It was found that these thicknesses are beneficial for a significant reduction of the gas permeability of the seal.

Further preferably the permeation barrier has a thickness below 50 µm, more preferably below 30 µm, and even more preferably below 20 µm. The low thickness of the permeation barrier makes it possible to provide the seal at low cost.

It was further found that it is beneficial for a low permeation of the seal when the first material comprises EVOH, Al_2O_3, Aluminum and/or mixtures thereof. The permeation barrier can for example be provided as aluminum foil or as EVOH film.

EVOH, which is the abbreviation of ethylene vinyl alcohol, is a copolymer that is formally built of the monomers ethylene and vinyl alcohol. Because the latter monomer mainly exists as its tautomer acetaldehyde, the copolymer is prepared by polymerization of ethylene and vinyl acetate to give the ethylene vinyl acetate (EVA) copolymer followed by hydrolysis.

The contact layer, which builds the outer surface of the seal consists of the second material. The second material comprises silicone rubber, PE, IIR and/or mixtures thereof.

Silicone rubber is a polysiloxane, i.e. a polymer made up of siloxane $-R_2Si-O-SiR_2-$, where R is an organic group. Particularly preferred is methyl vinyl silicone rubber – or in short VMQ – a silicon rubber where some of the organic groups are methyl groups and others are vinyl groups.

PE, the abbreviation of Polyethylene (IUPAC name: polyethene or poly(methylene)), is a polymer having the chemical formula $(C_2H_4)_n$. PE is usually a mixture of similar polymers of ethylene, with various values of n.

IIR, the abbreviation of isobutylene isoprene rubber, is also called butyl rubber and is a copolymer of isobutylene with isoprene, preferably of 95 mol% to 99 mol% isobutylene and 1 mol% to 5 mol% isoprene.

As already mentioned, the seal has a toroid shape. Having a toroid shape means in the context of this invention, that the outer surface of the seal corresponds to a surface of revolution with a hole in the middle. For example, when a rectangle is rotated around an axis or revolution that is parallel to one of the edges of the rectangle, then a toroid is produced in this case a hollow rectangle-section ring.

In principle a cross-section area of the seal along a cross-section comprising the axis of revolution can have any form. In the above given example for the toroid, the form of the cross-section area would be a rectangle. Other shapes are possible, for example in case the cross-section area has a form of an X, an X-Ring (also called four-lip seal) is provided. According to a preferred embodiment of the invention, a seal is provided wherein in the cross-section comprising the axis of revolution of the toroid, the seal has a circular cross-section area. Alternatively or additionally the seal is preferably configured as O-ring. In other words, the seal has preferably the shape of a torus.

The seal can be used for dynamic sealing applications. Preferably the seal is used for static sealing applications. Particular preferably the seal is configured as gasket and used to seal joints, flanges, and other mating surfaces of the high or medium voltage device.

According to another preferred embodiment of the invention, the permeation barrier is directly attached to the contact layer. In other words, it is preferred that there is no additional layer between the permeation barrier and the contact layer of the seal. This makes the structure of the seal simple.

It is possible that the seal comprises one permeation barrier. However, it is also possible that the seal comprises a plurality of permeation barriers. Several permeation barriers can further decrease the permeation of the seal. In this regard and according to a further preferred embodiment of the invention, the seal comprises a plurality of permeation barriers being spaced apart from each other.

As already mentioned, the outer surface of the seal is at least partially formed by the contact layer. Preferably at least 80 %, more preferably at least 90 % and even more preferably at least 95 % of the outer surface is formed by the contact layer.

Particularly preferably the outer surface of the seal is solely formed by the contact layer. Thus, the permeation barrier is preferably entirely embedded inside the seal.

According to another preferred embodiment, a seal is provided, wherein in a cross-section comprising an axis of revolution of the toroid, the permeation barrier has the form of a circle. It may also be possible that the permeation barrier has the form of another closed shape, such as an ellipse. Having a permeation barrier that has in the cross-section comprising the axis of revolution the form of a closed shape and preferably the form of a circle is especially preferred for seals being configured as O-rings and/or for seals where the seal itself has in the cross-section comprising the axis of revolution of the toroid, the circular cross-section area.

In an alternative preferred embodiment, a seal is provided, wherein in the cross-section comprising the axis of revolution of the toroid, the permeation barrier has the form of a line, a straight line, a bent line, a wavy line, and/or a circular arc. In other words, in this preferred embodiment the permeation barrier has not the form of a closed shape. This form of the permeation barrier is also possible for seals being configured as O-rings and/or for seals where the seal itself has in the cross-section comprising the axis of revolution of the toroid, the circular cross-section area.

Furthermore, in case the seal comprises a plurality of permeation barriers, it is further preferred that all of the permeation barriers have in the cross-section comprising the axis of revolution of the toroid, a form of a circle. Further preferably the plurality of permeation barriers is centered around a common center. Thus, the space in between the permeation barriers has the same thickness along the circle.

According to a further preferred embodiment of the invention, the seal comprises a support structure and wherein the support structure is directly attached to the permeation barrier. Further preferably the permeation barrier is sandwiched in between the support structure and the contact layer.

In case the seal comprises several permeation barriers it is further preferred that the support structure is directly attached to at least one of the several permeation barriers.

In general, it is possible that the support structure is made of the same material as the contact layer. However, according to a preferred embodiment of the invention, the support structure consists of a third material, and wherein the third material comprises PET, silicone rubber, EPDM and/or mixtures thereof.

PET – the abbreviation of polyethylene terephthalate – is a polyester and consists of repeating ($C_{10}H_8O_4$) units.

EPDM, also called EPDM rubber (ethylene propylene diene monomer rubber) is a terpolymer of ethylene, propylene and a third diene. The third diene is preferably ethylidene norbornene (ENB), dicyclopentadiene (DCPD), and/or vinyl norbornene (VNB).

Further preferably it is also possible that not only the third material and/or the support structure but also the second material and/or the contact layer comprises EPDM.

According to another preferred embodiment of the invention the second material and/or the third material is a thermoplastic elastomer. Further preferably the second material and the third material are a thermoplastic elastomer. Thermoplastic elastomers are a type of material that behave like an elastomer at room temperature but can be processed at elevated temperatures like a thermoplastic. Thermoplastic elastomers have thus the ability to be stretched to moderate elongations and, upon the removal of stress, essentially return to its original shape. They can further be processed as a melt at elevated temperature. Using thermoplastic elastomers for the support structure and/or the contact layer makes producing the seal easier and more cost effective.

Further preferably the second and/or third material comprise, nitrile rubber and/or vulcanized rubber. Nitrile rubber, also known as nitrile butadiene rubber (NBR) is a synthetic rubber derived from acrylonitrile (ACN) and butadiene. Also other rubbers that have been hardened by a vulcanization process can be used as support structure and/or the contact layer.

Particularly preferred are the following material combinations for the seal regarding the support structure, the permeation barrier, and the contact layer:

In one preferred embodiment the support structure and/or the third material comprises silicone rubber, the permeation barrier and/or the first material comprises EVOH and the contact layer and/or the second material comprises silicone rubber.

In another preferred embodiment the support structure and/or the third material comprises PET, the permeation barrier and/or the first material comprises EVOH and the contact layer and/or the second material comprises PE.

In yet another preferred embodiment the support structure and/or the third material comprises PET, the permeation barrier and/or the first material comprises Aluminum foil and the contact layer and/or the second material comprises PE.

In another preferred embodiment the support structure and/or the third material comprises EPDM, the permeation barrier and/or the first material comprises Aluminum foil or EVOH and the contact layer and/or the second material comprises IIR.

In a further preferred embodiment, the support structure and/or the third material is a thermoplastic elastomer, the first material comprises EVOH and the contact layer and/or the second material is a thermoplastic elastomer.

Furthermore, for seals comprising a plurality of permeation barriers that are spaced apart from each other, it is further preferred that the material in between the permeation barrier comprises PET, silicone rubber, EPDM, PE, IIR and/or mixtures thereof.

With regard to the support structure and according to another preferred embodiment of the invention, a seal is provided, wherein in the cross-section comprising the axis of revolution of the toroid the support structure has a circular cross-section area. This is particularly preferred for seals being configured as O-rings and/or for seals where the seal itself has in the cross-section comprising the axis of revolution of the toroid, the circular cross-section area and/or for seals where the permeation barrier has in the cross-section comprising the axis of revolution of the toroid the form of a circle.

In an alternative preferred embodiment of the invention a seal is provided, wherein in the cross-section comprising the axis of revolution of the toroid, the permeation barrier has the form of a spiral. In this case it is also possible that the seal is free of a support structure.

In connection to this and according to another preferred embodiment of the invention, a seal is provided, wherein in the cross-section comprising the axis of revolution of the toroid the contact layer and/or the support structure has the form of a spiral. This is particularly preferred for seals where the permeation barrier has in the cross-section comprising the axis of revolution the form of a spiral.

The invention further relates to a method for producing the above-described seal, comprising the steps of

- Forming the permeation barrier by applying the first material onto a support structure, and
- Forming the contact layer by applying the second material onto the permeation barrier, such that the outer surface of the seal is solely formed by the contact layer.

The seal produced by this method preferably has a support structure having a circular cross-section area in the cross-section comprising the axis of revolution of the toroid. Further preferably the seal produced by this method has a permeation barrier that has a circular form in the cross-section comprising the axis of revolution of the toroid.

Further preferably the method comprises the step of providing a support structure having a toroid form, and the step of forming the permeation barrier by applying the first material onto a support structure comprise forming the permeation barrier on the provided support structure by applying the first material onto a support structure, such that an outer surface of the seal is solely formed by the permeation barrier. By these steps it is ensured that the permeation barrier has a circular form in the cross-section comprising the axis of revolution of the toroid.

For example, the permeation barrier can be applied by winding the first material in the form of strips around the support structure.

According to another preferred embodiment of the invention, the step of forming the permeation barrier by applying the first material onto the support structure is achieved by: co-extrusion of the support structure and the permeation barrier, winding of the permeation barrier around the support structure, molding the permeation barrier onto the support structure, physical or chemical vapor deposition of the permeation barrier onto the support structure, sputtering the permeation barrier onto the support structure, spraying of the permeation barrier onto the support structure, dip coating the permeation barrier onto the support structure, applying the permeation barrier onto the support structure by electrochemistry, and/or applying the permeation barrier onto the support structure by sol-gel.

The invention further relates to a method for producing the above-described seal, comprising the steps of

- providing a multilayer sheet comprising at least one layer forming the permeation barrier consisting of the first material and directly attached to the one layer a second layer forming the contact layer consisting of the second material,
- Forming the seal by rolling the multilayer sheet such that the outer surface of the seal is solely formed by the contact layer.

The seal produced by this method preferably has a permeation barrier having the form of a spiral in the cross-section comprising the axis of revolution of the toroid.

Further preferably the seal produced by this method has a contact layer having the form of a spiral in the cross-section comprising the axis of revolution of the toroid.

In case the provided multilayer sheet consists of two layers – i.e. the permeation barrier and the contact layer – the seal produced by the method is free of a support structure.

However it is also possible that the provided multilayer sheet comprises more than two layers, for example three layers: the permeation barrier, the contact layer, and a third layer forming the support structure consisting of the third material, wherein the permeation barrier is sandwiched in between the contact layer and the support structure. In this case the seal produced by this method has a support structure having the form of a spiral in the cross-section comprising the axis of revolution of the toroid.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

In the drawings:

Fig. 1 schematically shows a cross-section of a seal according to a preferred embodiment of the invention,

Fig. 2 schematically shows a cross-section of a seal according to a further preferred embodiment of the invention,

Fig. 3 schematically shows cross-sections of a seal according to further preferred embodiments of the invention,

Fig. 4 schematically shows a cross-section of a seal according to a further preferred embodiment of the invention,

Fig. 5 schematically shows a perspective view of a seal according to a further preferred embodiment of the invention,

Fig. 6 schematically shows permeation rates of CO_2 across different samples with a permeation barrier, and

Fig. 7 schematically shows an apparatus for producing a seal according to another preferred embodiment of the invention.

Description of embodiments

Figure 1 schematically shows a cross-section of a seal 10 for a gas insulated high or medium voltage device, according to a preferred embodiment of the invention. The seal 10 has a toroid shape and the cross-section shown in figure 1 is a cross section 12 comprising an axis of revolution 14 of the toroid. The seal 10 comprises a permeation barrier 16 consisting of a first material and further a contact layer 18 consisting of a second material. As can be seen in figure 1, an outer surface of the seal 10 is solely formed by the contact layer 18.

In this embodiment the first material – i.e. the material of the permeation barrier – comprises EVOH, and the second material – i.e. the material of the contact layer – comprises IIR. In this particular example, the permeation barrier consists of EVOH and the contact layer consists of IIR.

As can be seen in the embodiment in figure 1, in the cross-section 12 comprising the axis of revolution 14, the seal 10 has a circular cross-section area. In other words, in this embodiment the seal 10 is configured as O-ring. Furthermore, also the permeation barrier 16 has in the cross-section 12 comprising the axis of revolution 14 a form of a circle.

In this preferred embodiment, the seal 10 further comprises a support structure 20. The support structure 20 has in the in the cross-section 12 comprising the axis of revolution 14 a circular cross-section area. The permeation barrier 16 is sandwiched in between the support structure 20 and the contact layer 18. As can be seen in the embodiment in figure 1, the contact layer 18 is directly attached to the permeation barrier 16. Furthermore, the permeation barrier 16 is directly attached to the support structure 20. In this preferred embodiment the support structure 20 consists of a third material comprising EPDM, in this particular case the support structure consists of EPDM.

Figure 2 schematically shows a cross-section 12 of a seal 10 for a gas insulated high or medium voltage device, according to another preferred embodiment of the invention. The embodiment shown in figure 2 is quite similar to the embodiment shown in figure 1, and in the following only the differences are explained. In this embodiment the seal 10 comprises several permeation barriers 16, 16', 16''. All of the permeation barriers 16, 16', 16''have in the cross-section 12 comprising the axis of revolution 14 a form of a circle. The permeation barriers 16, 16', 16''are centered around a common center and are spaced apart from each other. The permeation barrier 16'' with the smallest radius is directly attached to the support structure 20 of the seal 10. The permeation barrier 16 with the greatest radius is directly attached to the contact layer 18 of the seal 10. In this embodiment, the material in between the permeation barriers is the same type of material as the support structure 20. Furthermore, the permeation barriers 16, 16', 16'' are all of the same type of material.

In the embodiment shown in figure 2 the first material – i.e. the material of the permeation barrier – comprises aluminum, the second material – i.e. the material of the contact layer – comprises PE, and the third material – i.e. the material of the support structure – comprises PET.

Figure 3 schematically shows cross-sections 12 of seals 10 for a gas insulated high or medium voltage device, according to other preferred embodiments of the invention. Three different embodiments a), b), and c) are shown in figure 3, illustrating different forms of the permeation barrier 16. In the embodiment a) the permeation barrier 16 has in the cross-section 12 comprising the axis of revolution 14 a form of a circle. In the embodiment shown in figure b) and c) the permeation barrier 16 has in the cross-section 12 comprising the axis of revolution 14 a form of a line. In the embodiment b) the line is a wavy line, while in the embodiment c) the line is a bent line.

In the embodiment a) the outer surface of the seal 10 is solely formed by the contact layer 18. In the embodiment b) and c) at least 95 % of the outer surface of the seal 10 is formed by the contact layer 18. Furthermore, in the embodiments b) and c), the seal 10 is free of a support structure 20 and only consists of the permeation barrier 16 and the contact layer 18. In all three embodiments a), b) and c) the permeation barrier 16 consists of EVOH. In the embodiment shown in a) the contact layer 18 as well as the support structure 20 are a thermoplastic elastomer. In the embedments shown in b) and c) the contact layer 18 is a thermoplastic elastomer.

Figure 4 schematically shows a cross-section 12 of a seal 10 for a gas insulated high or medium voltage device, according to another preferred embodiment of the invention. The inner structure of the seal 10 of the embodiment shown in figure 4 is different to the embodiments shown in figures 1 to 3. In the embodiment in figure 4, in the cross-section 12 comprising the axis of revolution 14 of the toroid, the permeation barrier 16 as well as the contact layer 18 have the form of a spiral. In this embodiment the seal 10 is free of a support structure 20.

Figure 4 also schematically shows how the seal 10 is produced. In a first step a bilayer sheet 22 consisting of the contact layer 18 and the permeation barrier 16 is provided. In a further step the seal 10 is formed by rolling the bilayer sheet 22 such that the outer surface of the seal 10 is solely formed by the contact layer 18.

Figure 5 schematically shows a perspective explosive view of a seal 10 according to a further preferred embodiment of the invention. In this embodiment the seal 10 has the same structure as the seal 10 shown in figure1:

The seal 10 has a toroid shape and in the cross-section 12 comprising an axis of revolution 14 of the toroid, the seal 10, the permeation barrier 16, and the support structure 20 have a circular form. The outer surface of the seal 10 is solely formed by the contact layer 18.

Figure 5 also illustrates how the seal 10 is produced. In a first step the support structure 20 is provided. In this embodiment the support structure consists of PET. Afterwards strips of aluminum foil are wound around the support structure to form the permeation barrier 16. Afterwards, the contact layer 18 consisting of PE is applied to the permeation barrier 16 to form the outer surface of the seal 10.

Figure 6 schematically shows permeation rates of CO_2 across different samples with a permeation barrier. In particular figure 5 shows the permeation rates of CO_2 in ppm/h on the y-axis 24 across different samples with a permeation barrier 16. For determining the permeation rates a sandwich structure 26 consisting of a first layer 28 an intermediate barrier layer 30 as permeation barrier 16, and a further layer 32 was provided, and the sandwich structure 26 was inserted into a measuring chamber for determining the CO_2 leakage.

The following sandwich structures 26 were provided:

A) Sandwich structure consisting of a 12 μm thick layer of EVOH sandwiched in between two identical films of VMQ silicone rubber each with a thickness of 1 mm.

B) Sandwich structure consisting of 5 μm thick layer of EVOH sandwiched in between a 12 μm thick film of PET and an 80 μm thick film of PE.

C) Sandwich structure consisting of 8 μm thick layer of aluminium foil sandwiched in between a 12 μm thick film of PET and an 85 μm thick film of PE.

For the non-symmetrical samples B and C, the gas flow was measured in the direction from the PET towards the PE. The measurements were performed after one week 34, two weeks 36, three weeks 38, and seven weeks 40.

The obtained results were compared to a reference sample R made of IIR having a thickness of 2 mm.

One can clearly see in figure 6 that the leakage rate for the three samples A, B, C was significantly lower compared to the reference sample R made of IIR rubber.

The leakage rate was measured after prolonged exposition to CO_2 until the equilibrium state for the reference sample R was reached. For the reference sample R after seven weeks 40, the leakage rate was almost 28 ppm/h, whereas for the samples A, B, and C the CO_2 leakage rate was below detection limit even after seven weeks 40.

Figure 7 schematically shows an apparatus 42 for producing a seal 10 according to another preferred embodiment of the invention. The apparatus 42 is an apparatus configured for a co-extrusion process, in particular a head for co-extrusion in order to produce a seal 10 comprising the permeation barrier 16. As is illustrated in figure 7, the first material for forming the permeation barrier 16, the second material for forming the contact layer 18, and the third material for forming the support structure 20, are all simultaneously extruded and delivered to the extrusion head to form the seal 10 with the embedded permeation barrier 16. A thickness of the support structure 20, the permeation barrier 16, and the contact layer 18 are controlled by the relative speeds and sizes of the individual extruders delivering the materials.

While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosed, and the appended claims. In the claims, the word “comprising” does not exclude other elements or steps, and the indefinite article “a” or “an” does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting scope.

Reference signs list

10	seal
12	cross-section
14	axis of revolution
16	permeation barrier
18	contact layer
20	support structure
22	bilayer sheet
24	y-axis, CO_2 permeation rate in ppm/h
26	sandwich structure
28	first layer
30	intermediate barrier layer as permeation barrier
32	further layer
34	permeation rate after one week
36	permeation rate after two weeks
38	permeation rate after three weeks
40	permeation rate after seven weeks
42	apparatus, head for co-extrusion

A	sample according to the invention
B	sample according to the invention
C	sample according to the invention
R	reference sample

Claims

1. Seal (10) for a gas insulated high or medium voltage device, the seal (10) having a toroid shape and comprising

   a permeation barrier (16) consisting of a first material, and

   a contact layer (18) consisting of a second material,

   wherein an outer surface of the seal (10) is at least partially formed by the contact layer (18),

   wherein the first material comprises EVOH, Al_2O_3, Aluminum and/or mixtures thereof, and

   wherein the second material comprises silicone rubber, PE, IIR and/or mixtures thereof.

2. The seal (10) according to the previous claim, wherein in a cross-section (12) comprising an axis of revolution (14) of the toroid, the seal (10) has a circular cross-section area and/or wherein the seal (10) is configured as O-ring, and/or wherein the seal (10) is configured as gasket.

3. The seal (10) according to any of the previous claims, wherein the permeation barrier (16) is directly attached to the contact layer (18) and/or wherein the seal (10) comprises a plurality of permeation barriers (16, 116', 16'') being spaced apart from each other.

4. The seal (10) according to any of the previous claims, wherein the outer surface of the seal (10) is solely formed by the contact layer (18), and/or wherein in a cross-section (12) comprising an axis of revolution (14) of the toroid, the permeation barrier (16) has the form of a circle.

5. The seal (10) according to any of the previous claims, wherein the seal (10) comprises a support structure (20) and wherein the support structure (20) is directly attached to the permeation barrier (16).

6. The seal (10) according to the previous claim, wherein the support structure (20) consists of a third material, and wherein the third material comprises PET, silicone rubber, EPDM and/or mixtures thereof.

7. The seal (10) according to any of the previous claims, wherein the second material and/or the third material is a thermoplastic elastomer.

8. The seal (10) according to any of the two previous claims, wherein in a cross-section (12) comprising an axis of revolution (14) of the toroid the support structure (20) has a circular cross-section area.

9. The seal (10) according to any of claims 1 to 3, wherein in a cross-section (12) comprising an axis of revolution (12) of the toroid, the permeation barrier (16) has the form of a spiral.

10. The seal (10) according to the previous claim, wherein in the cross-section (12) comprising the axis of revolution (14) of the toroid the contact layer (18) and/or the support structure (20) has the form of a spiral.

11. Gas insulated high or medium voltage device comprising a seal (10) according to any of the previous claims and an insulation gas.

12. Use of the seal (10) according to any of the previous seal claims for sealing a gas insulated high or medium voltage devices, such as a gas-insulated switchgear, a live tank breaker, a dead tank breaker, a circuit breaker, a voltage instrument transformer, a current instrument transformer, a gas-insulated transmission line, a bushing and/or a mixed technology switchgear, against a loss of an insulation gas of the high or medium voltage device.

13. Method for producing a seal (10) according to any of claims 1 to 8, comprising the steps of
    - Forming the permeation barrier (16) by applying the first material onto a support structure (20), and

- Forming the contact layer (18) by applying the second material onto the permeation barrier (16), such that the outer surface of the seal (10) is solely formed by the contact layer (16).

14. Method according to the previous claim, wherein the step of forming the permeation barrier (16) by applying the first material onto the support structure (20) is achieved by: co-extrusion of the support structure (20) and the permeation barrier (16), winding of the permeation barrier (16) around the support structure (20), molding the permeation barrier (16) onto the support structure (20), physical or chemical vapor deposition of the permeation barrier (16) onto the support structure (20), sputtering the permeation barrier (16) onto the support structure (20), spraying of the permeation barrier (16) onto the support structure (20), dip coating the permeation barrier (16) onto the support structure (20), applying the permeation barrier (16) onto the support structure (20) by electrochemistry, and/or applying the permeation barrier (16) onto the support structure (20) by sol-gel.

15. Method for producing a seal according to any of claims 1 to 3, 9 or 10, comprising the steps of
    - providing a multilayer sheet (22) comprising at least one layer forming the permeation barrier (16) consisting of the first material and directly attached to the one layer a second layer forming the contact layer (18) consisting of the second material,
    - Forming the seal (10) by rolling the multilayer sheet (22) such that the outer surface of the seal (10) is solely formed by the contact layer (18).

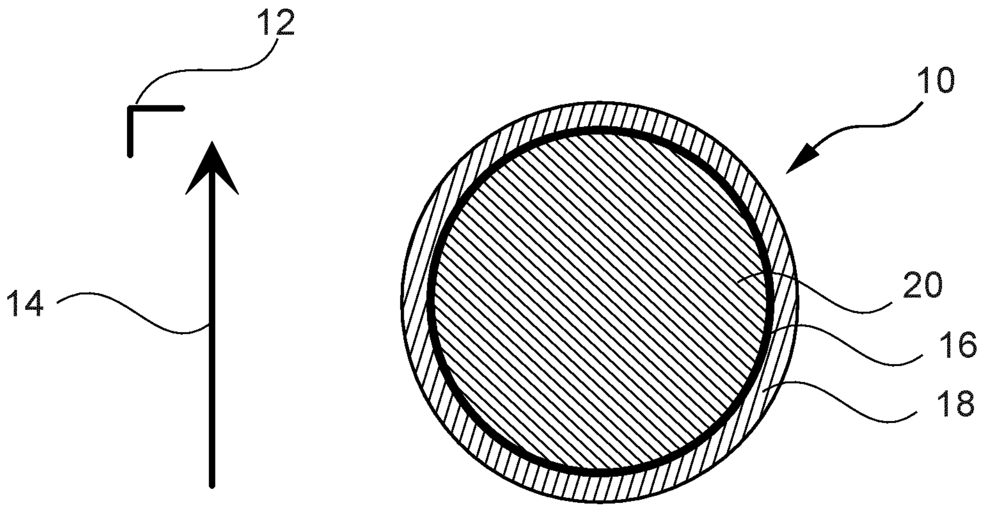

Fig. 1

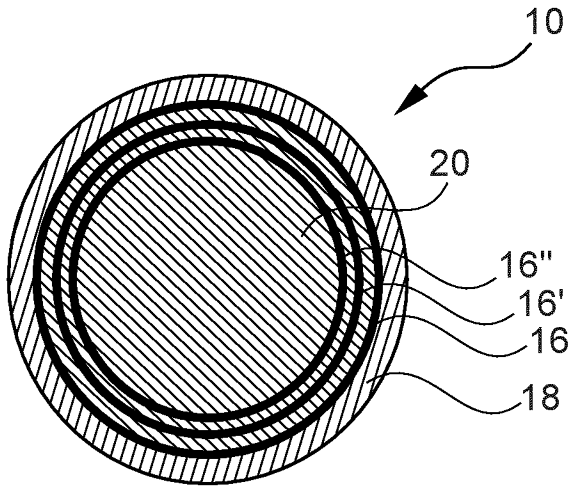

Fig. 2

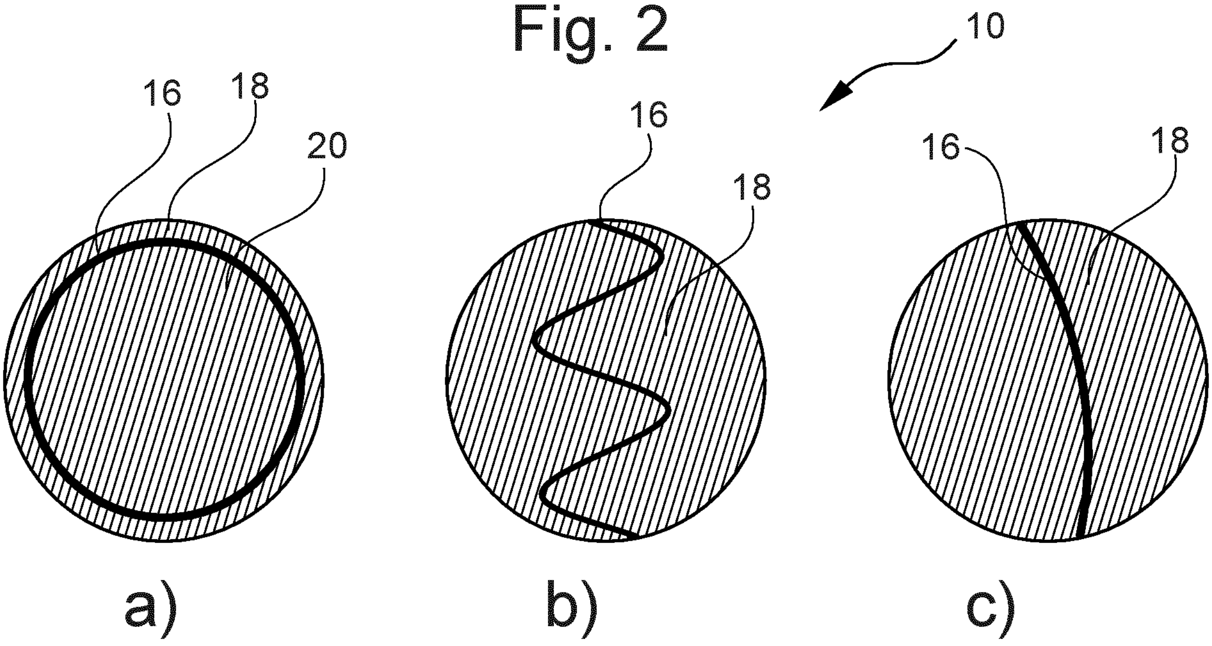

Fig. 3

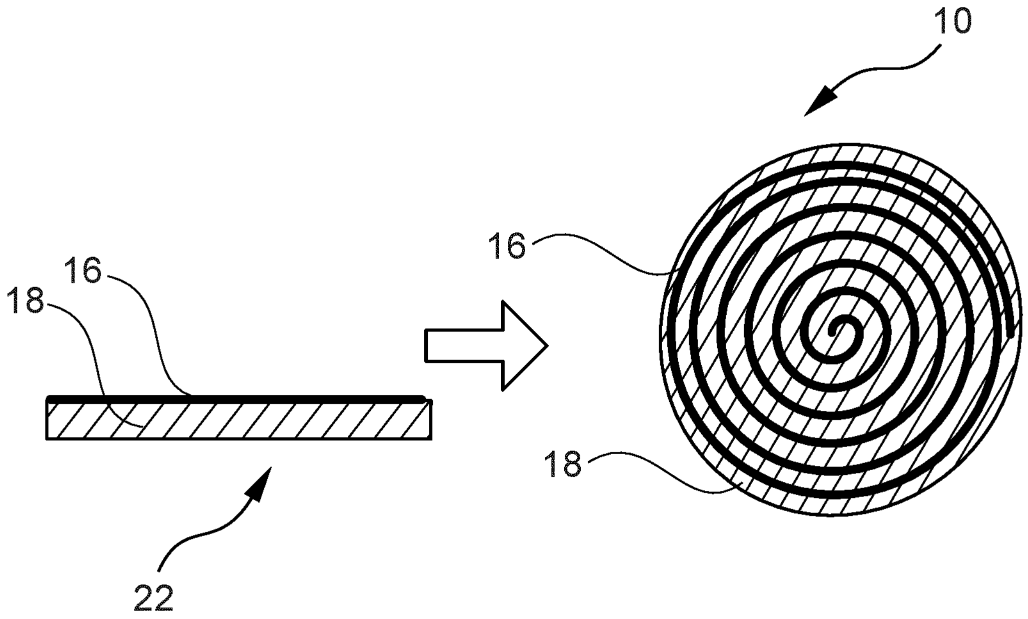

Fig. 4

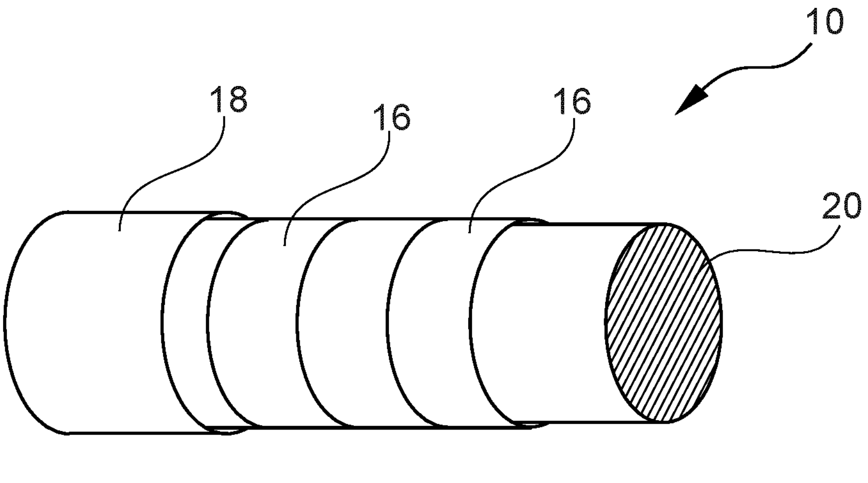

Fig. 5

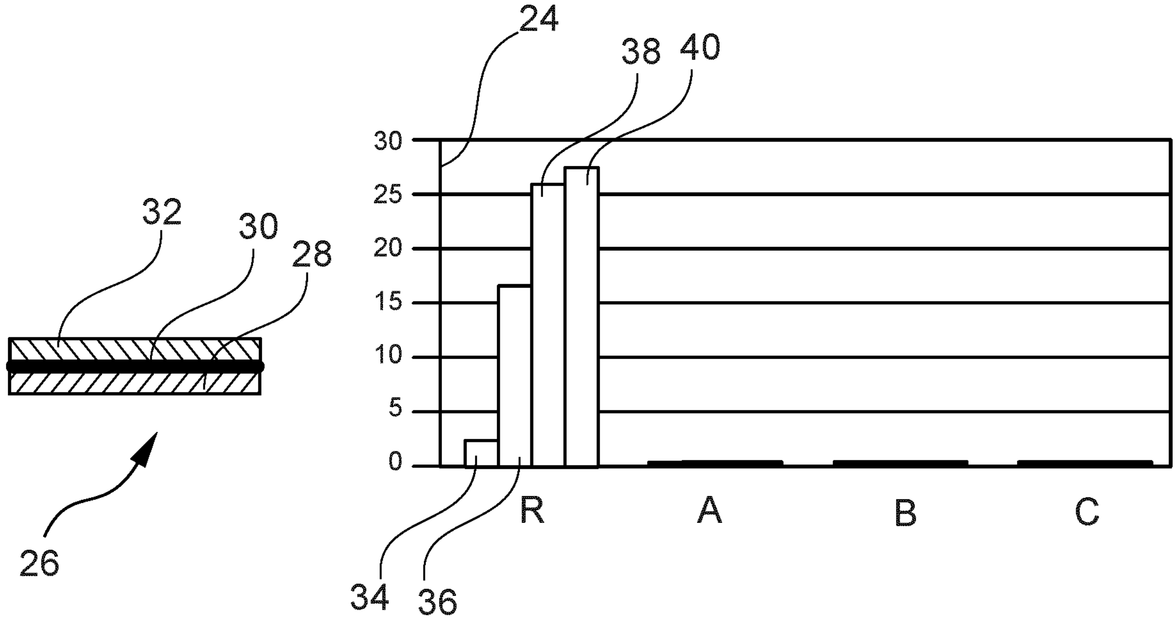

Fig. 6

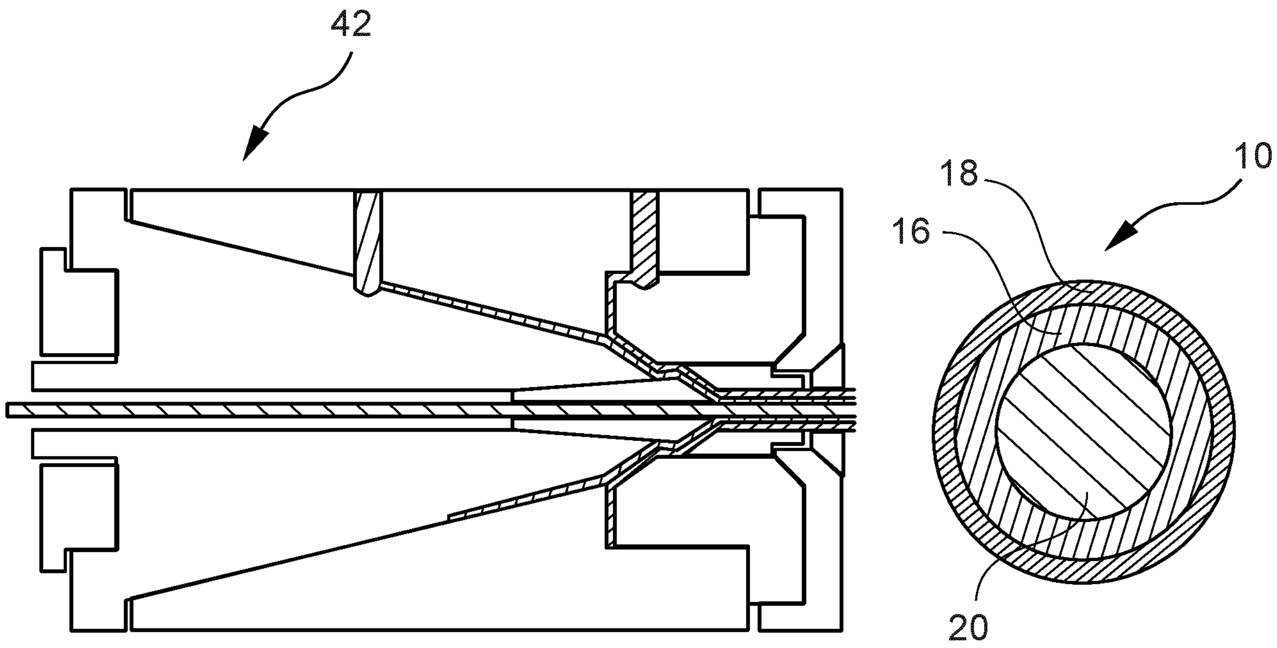

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2023/057829

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16J15/10 F16J15/12 F16J15/32
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F16J H02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2004/157035 A1 (GUIZZETTI ALLEN R [US] ET AL) 12 August 2004 (2004-08-12) figures 1, 2 paragraphs [0001], [0014] - [0016], [0020], [0027] -----	1-8,13, 14 1-8, 11-15
Y A	EP 3 330 580 A1 (ABB SCHWEIZ AG [CH]) 6 June 2018 (2018-06-06) figures 2, 4 paragraphs [0001], [0021] -----	1-8, 11-14 15
A	EP 2 722 566 A1 (FEI CO [US]) 23 April 2014 (2014-04-23) figure 2 -----	1-8, 11-15
Y	US 5 494 301 A (HAMILTON ELIZABETH M [US] ET AL) 27 February 1996 (1996-02-27) figure 8 -----	15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 October 2023	16/10/2023

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Bossi, Paolo

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2023/057829

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 2004157035	A1	12-08-2004	US	2004157035	A1	12-08-2004
			WO	2004071755	A1	26-08-2004
EP 3330580	A1	06-06-2018	NONE			
EP 2722566	A1	23-04-2014	CN	103775646	A	07-05-2014
			EP	2722566	A1	23-04-2014
			JP	5876859	B2	02-03-2016
			JP	2014085019	A	12-05-2014
			US	2014110903	A1	24-04-2014
US 5494301	A	27-02-1996	CA	2157283	A1	27-10-1994
			DE	69312745	T2	04-12-1997
			EP	0695405	A1	07-02-1996
			JP	H08509052	A	24-09-1996
			US	5486010	A	23-01-1996
			US	5494301	A	27-02-1996
			WO	9424467	A1	27-10-1994