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(54) **Pressure vessel for storing a pressurised fluid, such as hydrogen**

(57) A pressure vessel for storing a pressurised fluid, such as hydrogen, the pressure vessel comprising a shell comprising an access port provided with a port sealing surface, and a cap provided with a cap sealing surface and defining a longitudinal axis, wherein the access port and the cap are configured to receive and hold the cap in the access port with the cap sealing surface and the port sealing surface contacting each other to form an internal seal, the cap comprises an inner cap end, a recess is provided in the inner cap end, such that an axial extension is formed, and the cap sealing surface is provided at the axial extension.

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Title: Pressure vessel for storing a pressurised fluid, such as hydrogen

Field of the invention

The invention relates to a pressure vessel for storing a pressurised fluid, such as hydrogen. Such a pressure vessel comprises a shell having an access port that provides access to an internal storage space of the pressure vessel, and a cap arranged for closing the access port. An internal seal is formed between the access port and the cap in order avoid that the pressurized fluid stored in the pressure vessel will leak out of the pressure vessel.

Background of the invention

The invention is based on the insight that there is a need in the field of the art for a pressure vessel having an internal seal that is less susceptible to damage. Damage to the internal seal may lead to dangerous situations caused by leakage of the pressurised fluid. This is especially the case when the pressurised fluid is a highly flammable fluid, such as hydrogen.

Summary of the invention

The invention has the objective to provide an improved, or at least alternative, pressure vessel, method, and cap. In particular, the invention has the objective to provide a pressure vessel having an internal seal that is less susceptible to damage.

The objective is achieved by a pressure vessel for storing a pressurised fluid, such as hydrogen. The pressure vessel comprises a shell comprising an access port provided with a port sealing surface, and a cap provided with a cap sealing surface and defining a longitudinal axis. The access port and the cap are configured to receive and hold the cap in the access port with the cap sealing surface and the port sealing surface contacting each other to form an internal seal. The cap comprises an inner cap end, wherein a recess is provided in the inner cap end, such that an axial extension is formed. The cap sealing surface is provided at the axial extension.

By providing a pressure vessel cap wherein a recess is provided in the inner cap end, thereby forming an axial extension, and wherein the cap sealing surface is provided at the axial extension, the seal is located at a portion of the cap that may have much greater flexibility in radial direction as opposed to other portions of the cap. In addition, as the axial extension is adjacent to the recess, the seal can be in part actuated by the pressurized fluid acting on the axial extension. Accordingly, the invention allows to design a seal, whereat high stress concentrations that could lead to damage at the seal may be omitted, while ensuring sufficient sealing contact in loaded condition of the pressure vessel. Hence, with the present invention, the seal may be less susceptible to damage.

It was an insight of the inventors that reducing stresses, in particular tensile stresses, at the internal seal is particularly important for pressure vessels employing an internal seal that is subjected to pressurized hydrogen, as material degradation due to hydrogen adsorption may be accelerated when high material stresses are present at the internal seal.

Within the context of the present disclosure, with “inner cap end” is generally meant: the longitudinal end of the cap that is to be received inside the pressure vessel.

Advantageous embodiments of the present invention are described in the following.

In an embodiment of the pressure vessel according to the invention, the axial extension surrounds the recess, in particular, in radial direction with respect to the longitudinal axis.

In an embodiment of the pressure vessel according to the invention, the axial extension is radially outward with respect to the recess. In particular, the axial extension is with respect to the longitudinal axis located radially outward of the recess. As such, the axial extension may be more flexible in radial direction.

In an embodiment of the pressure vessel according to the invention, the axial extension comprises an inner extension side facing towards the longitudinal axis, wherein the inner extension side forms a boundary of the recess. In particular, the inner extension side may form a radial boundary of the recess.

In an embodiment of the pressure vessel according to the invention, the axial extension is an annular axial extension. In particular, the annular axial extension may have an annular cross section, in particular when viewed in longitudinal direction with respect to the longitudinal axis of the cap. In particular, the annulus of the annular axial extension is endless.

In an embodiment of the pressure vessel according to the invention, the recess has an annular shape. In particular, the recess may have an annular shape when viewed in longitudinal direction with respect to the longitudinal axis of the cap.

In an embodiment of the pressure vessel according to the invention, the cap comprises an inner recess surface. Such inner recess surface forms a boundary of the recess. In particular, the inner recess surface may extend perpendicular with respect to the longitudinal axis of the cap.

In an embodiment of the pressure vessel according to the invention, the axial extension extends in axial direction with respect to the longitudinal axis. In particular, the axial extension extends away from the inner recess surface.

In an embodiment of the pressure vessel according to the invention, the cap comprises a duct having an inner duct opening, wherein the axial extension is radially spaced from the inner duct opening. In particular, the axial extension surrounds the inner duct opening, more in particular, in radial direction with respect to the longitudinal axis.

In an embodiment of the pressure vessel according to the invention, the inner duct opening is provided at the inner recess surface.

In an embodiment of the pressure vessel according to the invention, the inner duct is located at, and aligned with, the longitudinal axis of the cap.

In embodiments comprising a duct, it is possible to configure seal parameters of the internal seal independently of the duct, more specifically independently of characteristics of the duct, such as specific dimensions (e.g. the diameter or length) of the duct. This is possible because characteristics of the axial extension, such as specific dimensions (e.g. the cap extension thickness) of the axial extension can be configured independently of the duct. As such, it is for example possible to adjust the flexibility in radial direction of the axial extension having the cap sealing surface, without influencing dimensions of the duct. Adjusting the flexibility of the axial extension will lead to adjusted seal parameters of the internal seal formed by the cap sealing surface and the port sealing surface contacting each other. This allows that seal parameters are selected which are favourable for reducing damage to the internal seal.

In an embodiment of the pressure vessel according to the invention, the axial extension extends in axial direction with respect to the longitudinal axis away from the duct.

In an embodiment of the pressure vessel according to the invention, the cap sealing surface is provided on the axial extension.

In an embodiment of the pressure vessel according to the invention, the cap sealing surface is axially spaced from the inner recess surface. In particular, the cap sealing surface is spaced from the inner recess surface in axial direction along the longitudinal axis.

In an embodiment of the pressure vessel according to the invention, the port sealing surface is axially spaced from the inner recess surface. In particular, the port sealing surface is spaced from the inner recess surface in axial direction along the longitudinal axis.

In an embodiment of the pressure vessel according to the invention, the inner recess surface extends transverse to the longitudinal axis.

In an embodiment of the pressure vessel according to the invention, the internal seal is a metal-to-metal seal. The metal-to-metal seal is less susceptible to damage, in particular, in cases where the pressure vessel is exposed to high temperature changes, when compared to elastomeric seals. As a result, the metal-to-metal seal has a high thermal stability.

In an embodiment of the pressure vessel according to the invention, the duct is configured to facilitate a flow of the pressurised fluid, such as hydrogen, in and/or out of the pressure vessel.

In an embodiment of the pressure vessel according to the invention, the cap comprises an outer duct opening and the duct extends from the inner duct opening until the outer duct opening.

In an embodiment of the pressure vessel according to the invention, the axial extension surrounds the longitudinal axis completely.

In an embodiment of the pressure vessel according to the invention, the inner recess surface is in radial direction with respect to the longitudinal axis located between the inner duct opening and the axial extension.

In an embodiment of the pressure vessel according to the invention, the axial extension comprises an adjoining end adjacent to the inner recess surface and a free end axially distanced from the inner recess surface.

In an embodiment of the pressure vessel according to the invention, the cap comprises a cap body, the cap body comprises a circumferential cap surface surrounding the longitudinal axis, and the axial extension comprises a cap extension thickness measured in radial direction with respect to the longitudinal axis at the axial extension, the cap body comprises a cap body thickness measured in radial direction with respect to the longitudinal axis from the longitudinal axis until the circumferential cap surface, and the cap extension thickness is smaller than the cap body thickness. In embodiments wherein the cap comprises a duct, the duct is provided in the cap body, and the cap body thickness is measured in radial direction with respect to the longitudinal axis from the duct until the circumferential cap surface. These embodiments allow that the axial extension is constructed with a higher flexibility than the cap body. This is beneficial to ensure that the seal parameters are mainly determined by the axial extension when compared with the cap body. The cap extension thickness may be the smallest cap extension thickness measured at the axial extension in the radial direction. The smallest cap extension thickness may be measured at an extension part of the axial extension extending in axial direction from, and including, the cap sealing surface until the adjoining end. The cap body thickness may be the smallest cap body thickness measured at the cap body, in particular, from the duct until the circumferential cap surface in the radial direction. The smallest cap body thickness may be measured at the inner recess surface.

In an embodiment of the pressure vessel according to the invention, the axial extension comprises a cap extension bending stiffness at the cap extension thickness, the cap body comprises a cap body bending stiffness at the cap body thickness, and the cap extension bending stiffness is smaller than the cap body bending stiffness.

In an embodiment of the pressure vessel according to the invention, the axial extension and the cap body are made from a same material, such as a same metal, and wherein preferably the axial extension and the cap body are integrally formed.

In an embodiment of the pressure vessel according to the invention, the cap comprises an inner cap section configured to be located inside the access port and an outer cap section configured to be located outside the access port.

In an embodiment of the pressure vessel according to the invention, the axial extension and the cap body are part of the inner cap section.

In an embodiment of the pressure vessel according to the invention, the inner duct opening is located at the inner cap section and the outer duct opening is located at the outer cap section.

In an embodiment of the pressure vessel according to the invention, the axial extension extends away from the outer cap section.

In an embodiment of the pressure vessel according to the invention, the duct has a circular cross section. In particular, the duct is circular when viewed in a cross sectional view in a plane perpendicular to the longitudinal axis.

In an embodiment of the pressure vessel according to the invention, the duct extends in line with the longitudinal axis.

In an embodiment of the pressure vessel according to the invention, the axial extension comprises an inner extension side facing towards the longitudinal axis and an outer extension side facing away from the longitudinal axis and the cap sealing surface is located at the outer extension side.

In an embodiment of the pressure vessel according to the invention, the cap sealing surface surrounds the longitudinal axis completely.

In an embodiment of the pressure vessel according to the invention, the axial extension comprises an inner extension surface facing towards the longitudinal axis and a transition surface connecting (or adjoining) the inner extension surface with the inner recess surface, and the transition surface forms a rounded corner extending along a radius R when viewed in a longitudinal sectional view with respect to the longitudinal axis. This provides additional structural integrity to the axial extension.

In an embodiment of the pressure vessel according to the invention, the access port defines a further longitudinal axis and the port sealing surface faces towards the further longitudinal axis.

In an embodiment of the pressure vessel according to the invention, the port sealing surface surrounds the further longitudinal axis completely.

In an embodiment of the pressure vessel according to the invention, the axial extension comprises a cap extension thickness measured in radial direction with respect to the longitudinal axis at the axial extension, the access port comprises an outer port surface and a port thickness measured in a further radial direction with respect to the further longitudinal axis from the port sealing surface until the outer port surface, and the port thickness is larger than the cap extension thickness. This allows that the axial extension is constructed with a higher flexibility than the access port. This tends to ensure that if the internal seal is damaged, most of the damage will occur at the cap, more specifically at the axial extension, rather than at the access port. The cap extension thickness may be the smallest cap extension thickness measured at the axial extension in the radial direction. The smallest cap extension thickness may be measured at an extension part of the axial extension extending in axial direction from, and including, the cap sealing surface until the adjoining end. The port thickness may be the smallest port thickness measured at the access port in the further radial direction. The smallest port thickness may be measured at the port sealing surface.

In an embodiment of the pressure vessel according to the invention, the access port comprises a port bending stiffness at the port thickness, the axial extension comprises a cap extension bending stiffness at the cap extension thickness, and the port bending stiffness is higher than the cap extension bending stiffness.

In an embodiment of the pressure vessel according to the invention, the access port and the axial extension and made from a same material, such as a same metal.

In an embodiment of the pressure vessel according to the invention, the access port comprises an outer access opening and a female threaded zone, the cap comprises a male treaded zone, the female threaded zone and the male threaded zone are configured for rotational engagement with each other, and the female threaded zone is located closer to the outer access opening than the port sealing surface. An advantage of this embodiment is that the threaded zones are not exposed to the pressurized fluid, in particular the hydrogen stored in the pressure vessel.

In an embodiment of the pressure vessel according to the invention, the female threaded zone and the male threaded zone comprise non-tapered threads.

In an embodiment of the pressure vessel according to the invention, the female threaded zone is located closer to the outer access opening than the port sealing surface, in particular, when viewed along the further longitudinal axis.

In an embodiment of the pressure vessel according to the invention, the access port and the cap are free from a seal located closer to the outer access opening than the female threaded zone.

In an embodiment of the pressure vessel according to the invention, the access port and the cap are free from an external seal.

An advantage of the above embodiments is, that, in case of internal seal failure, hydrogen may be released from the hydrogen pressure vessel immediately along the threaded zones, as opposed to becoming trapped at the threaded zones. Trapped hydrogen may form a safety hazard.

In an embodiment of the pressure vessel according to the invention, the cap sealing surface is toroidal. In particular, the cap sealing surface may be convex. More in particular, the cap sealing surface may have a convex longitudinal section, in particular when viewed in a longitudinal sectional view with respect to the longitudinal axis.

In an embodiment of the pressure vessel according to the invention, the port sealing surface is conical.

In an embodiment of the pressure vessel according to the invention, the conical port sealing surface becomes wider in a first direction along the further longitudinal axis of the access port and towards the outer access opening.

In an embodiment of the pressure vessel according to the invention, the access port and the cap are free from an elastomeric seal.

In an embodiment of the pressure vessel according to the invention, the access port and the cap are configured to hold the cap in a sealing position in the access port with the cap sealing surface and the port sealing surface contacting each other to form the internal seal.

In an embodiment of the pressure vessel according to the invention, the access port comprises a port stop shoulder, the cap comprises a cap stop shoulder, and the port stop shoulder and the cap stop shoulder are configured to contact each other to form the internal seal when the cap is located in the sealing position.

In an embodiment of the pressure vessel according to the invention, the longitudinal axis of the cap positioned in the sealing position coincides with the further longitudinal of the access port.

In an embodiment of the pressure vessel according to the invention, the pressure vessel is configured to store the pressurised fluid at a fluid pressure of 500 bar or higher, preferably 1000 bar or higher.

In an embodiment of the pressure vessel according to the invention, the access port provides access to a storage space for storing the pressurised fluid in the pressure vessel.

In an embodiment of the pressure vessel according to the invention, a valve, such as a pressure valve, is connected to the duct. Such valve is arranged to control the flow of fluid in and/or out of the pressure vessel.

It will be clear to the skilled person that the invention also relates to embodiments of the pressure vessel comprising the features of any combination of any number of the above defined embodiments of the pressure vessel according to the invention.

The invention further relates to a pressure vessel for storing a pressurised fluid, such as hydrogen, said pressure vessel comprising a shell comprising an access port provided with a port sealing surface, and a cap provided with a cap sealing surface and defining a longitudinal axis, wherein the access port and the cap are configured to receive and hold the cap in the access port with the cap sealing surface and the port sealing surface contacting each other to form an internal seal, the cap comprises an inner cap surface and a duct having an inner duct opening provided at the inner cap surface, the cap further comprises an axial extension extending in axial direction with respect to, in particular from, the inner cap surface, and the cap sealing surface is provided at the axial extension. In particular, the axial extension may be adjoining the inner cap surface.

It will be clear to the skilled person that the invention also relates to embodiments of the above pressure vessel comprising the features of the pressure vessel of any combination of any number of the above defined embodiments of the pressure vessel according to the invention.

The invention further relates to a method for sealing a pressure vessel for storing a pressurised fluid, such as hydrogen, according to the invention, the method comprising placing the cap in the access port and forming an internal seal with the cap sealing surface and the port sealing surface contacting each other.

It will be clear to the skilled person that the invention also relates to embodiments of the method comprising the features of the pressure vessel of any combination of any number of the above defined embodiments of the pressure vessel according to the invention.

The invention further relates to a cap for a pressure vessel, comprising an inner cap end, a recess provided in the inner cap end, such that an axial extension is formed, and a cap sealing surface provided at the axial extension.

It will be clear to the skilled person that the invention also relates to embodiments of the cap comprising the features of the cap of any combination of any number of the above defined embodiments of the pressure vessel according to the invention.

Brief description of the drawings

Embodiments of the pressure vessel according to the invention, the method according to the invention and the cap according to the invention will be described by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

Figures 1 schematically shows a view in perspective of an embodiment of the pressure vessel according to the invention,

Figure 2 schematically shows a view in longitudinal section of the pressure vessel of Fig. 1,

Figure 3A schematically shows a view in longitudinal section of an access port and a cap of the pressure vessel of Fig. 1,

Figure 3B schematically shows an enlarged view of part III-B of Fig. 3A,

Figure 3C schematically shows the view of Fig. 3B presenting results of a finite element analysis,

Figure 4A schematically shows a longitudinal sectional view of the access port of Fig. 3A,

Figure 4B schematically shows an enlarged view of part IV-B of Fig. 4A,

Figure 5A schematically shows a view in longitudinal section of the cap of Fig. 3A,

Figure 5B schematically shows an enlarged view of part V-B of Fig. 5A,

Figure 6 schematically shows a view in longitudinal section of a further access port and a further cap of the pressure vessel of fig. 1, and

Figure 7 schematically shows a view in longitudinal section of another embodiment of a cap in accordance with the invention.

Detailed description of the drawings

Figure 1 shows a view in perspective of an embodiment of the pressure vessel 1 according to the invention. The pressure vessel 1 is configured to store a pressurised fluid, more specifically hydrogen. The pressure vessel 1 is configured to store the pressurised fluid at a fluid pressure of 1000 bar or higher. In other examples, the pressure vessel 1 is configured to store the pressurised fluid at a fluid pressure of 500 bar or higher.

The pressure vessel 1 comprises a shell 2 having two access ports 3. Each access port 3 provides access to a storage space 41 for storing the pressurised fluid in the pressure vessel 1. In each of the access ports 3 a cap 5, 5' is provided.

Figure 2 shows a longitudinal section of the pressure vessel 1 of Fig. 1. The caps 5, 5' are of similar construction. The only difference between the caps is that cap 5 comprises a duct 12, whereas cap 5' is free from a duct. The access ports 3 are identical.

Each access port 3 is provided with a port sealing surface 4. Each cap 5, 5' is provided with a cap sealing surface 6. The access ports 3 and the caps 5 are configured to receive and hold one of the caps 5 in one of the access ports 3 with the cap sealing surface 6 and the port sealing surface 4 contacting each other to form an internal seal 10.

The cap 5, 5' extends in longitudinal (or axial) direction 46 along a (central) longitudinal axis 7. The cap 5, 5' comprises an inner cap end 8 that is, when the cap 5, 5' is mounted in the access port 3, situated inside the access port 3, and an outer cap end 51 that is located opposite to the inner cap end 8. The outer cap end 51 extends outside the access port 3. The cap 5, 5' extends in longitudinal direction along the longitudinal axis 7 from the inner cap end 8 to the outer cap end 51.

A recess 9 is provided in the inner cap end 8 so as to form an annular axial extension 14. The axial extension 14, and an inner recess surface 11, form a boundary of the recess 9. The axial extension 14 extends from the inner recess surface 11.

A cap sealing surface 6 is provided at, in particular on, the axial extension 14. This allows to configure the seal parameters of the internal seal 10 independently of rest of the cap 5, more specifically independently of characteristics of the cap 5, such as specific dimensions (e.g. the diameter) of the cap body 17.

Figure 3A shows a view in longitudinal section of the access port 3 and the cap 5 of the pressure vessel 1 shown in Figure 1. Figure 3B shows an enlarged view of part III-B of figure 3A. The axial extension 14 extends in axial direction 46 with respect to the longitudinal axis 7. The inner recess surface 11 extends transverse to the longitudinal axis 7. The duct 12 is configured to facilitate a flow of the pressurised fluid, such as hydrogen, in and/or out of the pressure vessel 1. A valve (not shown), such as a pressure valve, may be connected to the duct 12 in order to control the flow of pressurised fluid. The cap 5 comprises an outer duct opening 39 and the duct 12 extends from the inner duct opening 13 until the outer duct opening 39. The inner recess surface 11 is in radial direction 44 (see figure 5A) with respect to the longitudinal axis 7 located between the inner duct opening 13 and the axial extension 14. Further details of the access port 3 are shown in the figures 4A and 4B. Further details of the cap are shown in the figures 5A and 5B.

As mentioned, the cap 5 in Figure 1 comprises a duct 12 having an inner duct opening 13 provided at the inner recess surface 11. The duct 12 is circular when viewed in a cross sectional view in a plane perpendicular to the longitudinal axis 7. The duct 12 extends along the longitudinal axis 7. The axial extension 14 extends away from the duct 12.

By providing the cap sealing surface 6 at the axial extension 14 extending from the inner recess surface 11 and away from the duct 12, it is possible to configure seal parameters independently of the duct 12, more specifically independently of characteristics of the duct 12, such as specific dimensions (e.g. the diameter) of the duct 12. This is possible because characteristics of the axial extension 14, such as specific dimensions (e.g. the cap extension thickness Tc1) of the axial extension 14 can be configured independently of the duct 12. As such, it is for example possible to adjust the flexibility in radial direction 44 of the axial extension 14 having the cap sealing surface 6, without influencing dimensions of the duct 12. Adjusting the flexibility of the axial extension 14 will lead to adjusted seal parameters of the internal seal 10 formed by the cap sealing surface 6 and the port sealing surface 4 contacting each other. This allows that seal parameters are selected which are favourable for reducing damage to the internal seal 10.

The internal seal 10 is a metal-to-metal seal 16. The metal-to-metal seal 16 is less susceptible to damage resulting from high temperatures when compared to elastomeric seals. As a result, the metal-to-metal seal 16 has a high thermal stability. The access port 3 and the cap 5 are free from an elastomeric seal.

The cap sealing surface 6 is axially spaced from the inner recess surface 11 when viewed along the longitudinal axis 7. The port sealing surface 4 is also axially spaced from the inner recess surface 11 when viewed along the longitudinal axis 7.

The axial extension 14 surrounds the inner duct opening 13 and is radially spaced from the inner duct opening 13. The axial extension 14 surrounds the longitudinal axis 7 completely.

The cap comprises a cap body 17 in which the duct 12 is provided. The cap body 17 comprises a circumferential cap surface 18 surrounding the longitudinal axis 7. The circumferential cap surface 18 has a circular cross section. The axial extension 14 comprises a cap extension thickness Tc1 measured in radial direction 44 with respect to the longitudinal axis 7 at the axial extension 14. The cap body 17 comprises a cap body thickness Tc2 measured in radial direction 44 with respect to the longitudinal axis 7 from the duct 12 until the circumferential cap surface 18. The cap extension thickness Tc1 is smaller than the cap body thickness Tc2. This allows that the axial extension 14 is constructed with a higher flexibility than the cap body 17 (see also figure 3C). This is beneficial to ensure that the seal parameters are mainly determined by the axial extension 14 when compared with the cap body 17. The axial extension 14 comprises a cap extension bending stiffness Kc1 at the cap extension thickness Tc1. The cap body 17 comprises a cap body bending stiffness Kc2 at the cap body thickness Tc2, and the cap extension bending stiffness Kc1 is smaller than the cap body bending stiffness Kc2.

The axial extension 14 comprises an adjoining end 23 adjacent to the inner recess surface 11 and a free end 24 axially distanced from the inner recess surface 11. The free end 24 terminates in an axial extension inner end surface 50. The inner end surface 50 is annular, and extends transverse with respect to the longitudinal axis 7. The inner end surface 50 is an end surface of the inner end 8 of the cap 5, 5'.

The cap extension thickness Tc1 is the smallest cap extension thickness Tc1 measured at the axial extension 14 in the radial direction 44. The smallest cap extension thickness Tc1 is measured at an extension part 40 of the axial extension 14 extending in axial direction 46 (see also figure 5B) from, and including, the cap sealing surface 6 until the adjoining end 23. The cap body thickness Tc2 is the smallest cap body thickness Tc2 measured at the cap body 17 from the duct 12 until the circumferential cap surface 18 in the radial direction 44. The smallest cap body thickness Tc2 is measured at the inner recess surface 11.

The access port 3 defines a further longitudinal axis 28 and the port sealing surface 4 faces towards the further longitudinal axis 28. The port sealing surface 4 surrounds the further longitudinal axis 28 completely.

The access port 3 comprises an outer port surface 31 and a port thickness Tp measured in a further radial direction 29 with respect to the further longitudinal axis 28 from the port sealing surface 4 until the outer port surface 31. The further radial direction 29 and a further axial direction 30 with respect to the further longitudinal axis 28 are indicated in figure 4A. The port thickness Tp is larger than the cap extension thickness Tc1 mentioned above. This allows that the axial extension 14 is constructed with a higher flexibility than the access port 3. This is beneficial for the compressive hoop stresses provided on the axial extension 14 and the tensile hoop stresses on the access port 3 (see also figure 3C). In addition, this tends to ensure that if the internal seal 10 is damaged, the damage (or most of the damage) will occur at the cap 5, more specifically the axial extension 14 and the cap sealing surface 6, and not at the access port 3, more specifically the port sealing surface 4. The access port 3 comprises a port bending stiffness Kp at the port thickness Tp. The axial extension 14 comprises a cap extension bending stiffness Kc1 at the cap extension thickness Tc1. The port bending stiffness Kp is higher than the cap extension bending stiffness Kc1. The port thickness Tp is the smallest port thickness Tp measured at the access port 3 in the further radial direction 29. The smallest port thickness Tp is measured at the port sealing surface 4.

The axial extension 14 comprises an inner extension surface 25 facing towards the longitudinal axis 7 and a transition surface 26 connecting the inner extension surface 25 with the inner recess surface 11. The inner extension surface 25, the transition surface 26, and the inner recess surface 11 together form a boundary of the recess 9.

The transition surface 26 forms a rounded corner 27 extending along a radius R when seen in a longitudinal sectional view with respect to the longitudinal axis 7. This provides additional structural integrity to the axial extension 14. The transition surface 26 is provided directly opposite to the cap sealing surface 6.

The axial extension 14 and the cap body 17 are made from a same material, more specifically metal. The axial extension 14 and the cap body 17 are integrally formed (i.e. the axial extension 14 and the cap body 17 are made of a single piece). In other words; the axial extension 14 and the cap body 17 each are part of a single piece of material. The access port 3 and the axial extension 14 and made from the same material. The shell 2 of the pressure vessel 1 is made from the same material. The shell 2 and the access port 3 are integrally formed.

The access port 3 and the cap 5 are configured to hold the cap 5 in a sealing position 15 in the access port 3 with the cap sealing surface 6 and the port sealing surface 4 contacting each other to form the internal seal. The access port 3 comprises a port stop shoulder 37. The cap comprises a cap stop shoulder 38. The port stop shoulder 37 and the cap stop shoulder 38 are configured to contact each other, wherein, upon contact, the sealing surfaces 4, 6 are in contact to form the internal seal 10. The longitudinal axis 7 of the cap positioned in the sealing position 15 coincides with the further longitudinal of the access port 3.

Figure 3C shows the results of a finite element analysis of the situation of figure 3B, wherein the cap is positioned in the sealing position 15. Figure 3C clearly shows that a first area 43 with the highest compression stresses caused in the access port 3 is much smaller than a second area 45 of the highest compression stresses in the cap 5. If the internal seal 10 is damaged by for example plastic deformation caused by high compression forces, the damage (or most of the damage) tends to occur at the cap 5, more specifically the axial extension 14. This is beneficial, because in practice it is cheaper to replace and/or repair the cap 5 rather than the shell 2 having the access port 3.

The access port 3 comprises an outer access opening 32 and a female threaded zone 33. The cap 5 comprises a male threaded zone 34. The female threaded zone 33 and the male threaded zone 34 are configured for rotational engagement with each other. The female threaded zone 33 is located closer to the outer access opening 32 than the port sealing surface 4. The female threaded zone 33 and the male threaded zone 34 comprise non-tapered threads.

The female threaded zone 33 is located closer to the outer access opening 32 than the port sealing surface 4 when seen along the further longitudinal axis 28. The access port 3 and the cap 5 are free from a seal located closer to the outer access opening 32 than the female threaded zone 33. Hence, the access port 3 and the cap 5 are free from an external seal.

The female threaded zone 33 comprises a female thread 52. The female thread 52 comprises a female stab flank 53 and a female load flank 54. The male threaded zone 34 comprises a male thread 55. The male thread 55 comprises a male stab flank 56 and a male load flank 57. The female stab flank 53 faces towards the outer access opening 32, and the female load flank 54 faces away from the outer access opening 32. The male stab flank 56 faces towards the inner cap end 8. As can be seen in Figure 3C, when the cap 5 has been made up with the access port 3, the stab flanks 53, 56 are located at a distance 58 from each other, whereas the load flanks 54, 57 are in contact with each other. The internal seal 10 seals the access port 3 of the pressure vessel 1 such that hydrogen contained in the storage space 41 cannot reach the threaded zones 33, 34.

The cap 5 comprises an inner cap section 19 configured to be located inside the access port 3 and an outer cap section 20 configured to be located outside the access port 3. The axial extension 14 and the cap body 17 are part of the inner cap section 19. The inner duct opening 13 is located at the inner cap section 19 and the outer duct opening 39 is located at the outer cap section 20. The axial extension 14 extends away from the outer cap section 20.

The axial extension 14 is annular. The axial extension 14 comprises an inner extension side 21 facing towards the longitudinal axis 7 and an outer extension side 22 facing away from the longitudinal axis 7. The cap sealing surface 6 is located at the outer extension side 22. The cap sealing surface 6 surrounds the longitudinal axis 7 completely.

The cap sealing surface 6 is toroidal 35. The port sealing surface 4 is conical 36. The conical 36 port sealing surface 4 becomes wider in a first direction 42 along the further longitudinal axis 28 of the access port 3 and towards the outer access opening 32.

Figure 6 shows a view in longitudinal section of the access port 3 and the cap 5’ of the pressure vessel 1 in Figure 1. The only difference with respect to the access port 3 at the opposite end of the pressure vessel 1 holding cap 5 as shown in the figures 3A-C, 4A-B, and 5A-B, is that cap 5’ does not have a duct 12.

Similar to cap 5, the axial extension 14 of the cap 5’ surrounds the longitudinal axis 7 and is radially spaced from the longitudinal axis 7.

The cap body 17 of the cap 5’ comprises a further cap body thickness Tc3 measured in radial direction 44 with respect to the longitudinal axis 7 from the longitudinal axis 7 until the circumferential cap surface 18. The cap extension thickness Tc1 (as described above in relation to cap 5) is smaller than the further cap body thickness Tc3. This allows that the axial extension 14 is constructed with a higher flexibility than the cap body 17. This is beneficial to ensure that the seal parameters are mainly determined by the axial extension 14 when compared with the cap body 17.

The cap body 17 comprises a further cap body bending stiffness Kc3 at the further cap body thickness Tc3, and the cap extension bending stiffness Kc1 (as described above in relation to the cap 5) is smaller than the further cap body bending stiffness Kc3.

The further cap body thickness Tc3 is the smallest further cap body thickness Tc3 measured at the cap body 17 from the longitudinal axis 7 until the circumferential cap surface 18 in the radial direction 44. The smallest further cap body thickness Tc3 is measured at the inner recess surface 11.

Figure 7 shows another embodiment of the cap 5 in accordance with the present invention in longitudinal section. Similar to the embodiment of Figure 5A, the cap 5 comprises at the inner cap end 8 thereof a recess 9. However, different from the above described cap 5, the recess 9 has an annular shape, wherein an annular recess surface 11 is formed. The annular recess 9 is bound in radial direction by the axial extension 14; and by a central part 47 of the inner cap end 8, in particular by an outer side 48 of the central part 47 of the inner cap end 8. The annular recess 9 is bound in longitudinal direction by the inner recess surface 11. The outer side 48 faces away from the longitudinal axis 7. The duct opening 13 is provided in an inner cap end surface 49 of the central part 47 of the inner cap end 8. The inner cap end surface 49 is transverse with respect to the longitudinal axis 7. The inner cap end surface 49 and the axial extension inner end surface 50 of the axial extension 14 lie in the same transverse plane with respect to the longitudinal axis 7. As such, the axial extension 14 and the central part 47 are flush to each other in axial direction 46. It is, however, envisioned that the central part 47 can extend, in axial direction, more or less than the axial extension 14. An advantage of this embodiment is, that the inner extension side 21 may be safeguarded from turbulent fluid flows.

The longitudinal sections shown in the Figures are taken at longitudinal axis 7 and/or further longitudinal axis 28. Cross sections are taken in a plane perpendicular to the longitudinal axis 7 and/or further longitudinal axis 28.

As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure. Further, the terms and phrases used herein are not intended to be limiting, but rather, to provide an understandable description of the invention.

The terms "a" or "an", as used herein, are defined as one or more than one. The term plurality, as used herein, is defined as two or more than two. The term another, as used herein, is defined as at least a second or more. The terms including and/or having, as used herein, are defined as comprising (i.e., open language, not excluding other elements or steps). Any reference signs in the claims should not be construed as limiting the scope of the claims or the invention.

It will be apparent to those skilled in the art that various modifications can be made to the pressure vessel according to the invention, the method according to the invention, and the cap according to the invention shown in the figures without departing from the scope as defined in the claims.

CONCLUSIES

1. Drukvat voor het opslaan van een onder druk gehouden fluïdum, zoals waterstof, het drukvat omvattende:
- een omhulsel omvattende een toegangspoort die is voorzien van een poortafdichtoppervlak, en
- een kap die is voorzien van een kapafdichtoppervlak en die een longitudinale aslijn definieert, waarbij:
-- de toegangspoort en de kap zijn ingericht voor het ontvangen en houden van de kap in de toegangspoort waarbij het kapafdichtoppervlak en het poortafdichtoppervlak met elkaar in contact zijn om een interne afdichting te vormen,
-- de kap een binnenkapeinde omvat,
-- een uitsparing is verschaft in het binnenkapeinde, zodat een axiale uitbreiding is gevormd, en
-- het kapafdichtoppervlak is verschaft bij de axiale uitbreiding.

2. Drukvat volgens conclusie 1, waarbij de axiale uitbreiding de uitsparing omgeeft.

3. Drukvat volgens conclusie 1 of 2, waarbij de kap een doorgang met een binnendoorgangsopening omvat, en de axiale uitbreiding radiaal op afstand is gelegen van de binnendoorgangsopening.

4. Drukvat volgens een van de voorgaande conclusies, waarbij:
- de kap een kaplichaam omvat,
- het kaplichaam een kapomtrekoppervlak omvat dat de longitudinale aslijn omgeeft,
- de axiale uitbreiding een kapuitbreidingdikte omvat die wordt gemeten in radiale richting ten opzichte van de longitudinale aslijn bij de axiale uitbreiding,
- het kaplichaam een kaplichaamdikte omvat die wordt gemeten in radiale richting ten opzichte van de longtudinale aslijn tussen de longitudinale aslijn en het kapomtrekoppervlak, en
- de kapuitbreidingdikte kleiner is dan de kaplichaamdikte.

5. Drukvat volgens een van de voorgaande conclusies, waarbij de axiale uitbreiding verder een buitenuitbreidingzijde omvat die is weggericht van de longitudinale aslijn en het kapafdichtoppervlak is gelegen aan de buitenuitbreidingzijde.

6. Drukvat volgens een van de voorgaande conclusies, waarbij de kap een binnenuitsparingoppervlak omvat, en de axiale uitbreiding een binnenuitbreidingoppervlak dat is gericht naar de longitudinale aslijn en een transitieoppervlak dat het binnenuitbreidingoppervlak met het binnenuitsparingoppervlak verbindt omvat, en het transitieoppervlak een afgeronde hoek vormt die zich wanneer gezien in een langsdoorsnede aanzicht ten opzichte van de longitudinale aslijn uitstrekt langs een radius R.

7. Drukvat volgens een van de voorgaande conclusies, waarbij de toegangspoort een verdere longitudinale aslijn definieert en het poortafdichtoppervlak is gericht naar de verdere longitudinale aslijn.

8. Drukvat volgens een van de voorgaande conclusies, waarbij:
- de axiale uitbreiding een kapuitbreidingdikte omvat die wordt gemeten in radiale richting ten opzichte van de longitudinale aslijn bij de axiale uitbreiding,
- de toegangspoort een buitenpoortoppervlak en een poortdikte die wordt gemeten in een verdere radiale richting ten opzichte van de verdere longitudinale aslijn tussen het poortafdichtoppervlak en het buitenpoortoppervlak omvat, en
- de poortdikte groter is dan de kapuitbreidingdikte.

9. Drukvat volgens een van de voorgaande conclusies, waarbij:
- de toegangspoort een buitentoegangsopening en een vrouwelijke schroefdraadzone omvat,
- de kap een mannelijke schroefdraadzone omvat,
- de vrouwelijke schroefdraadzone en de mannelijke schroefdraadzone zijn ingericht om bij rotatie met elkaar aan te grijpen, en
- de vrouwelijke schroefdraadzone dichter bij de buitentoegangsopening is gelegen dan het poortafdichtoppervlak.

10. Drukvat volgens conclusie 9, waarbij de toegangspoort en de kap vrij zijn van een afdichting die dichter bij de toegangsopening is gelegen dan de vrouwelijke schroefdraadzone.

11. Drukvat volgens een van de voorgaande conclusies, waarbij het kapafdichtoppervlak torusvormig is.

12. Drukvat volgens een van de voorgaande conclusies, waarbij de toegangspoort en de kap vrij zijn van een elastomerische afdichting.

13. Werkwijze voor het afdichten van een drukvat voor het opslaan van een onder druk gehouden fluidum, zoals waterstof, volgens een van de voorgaande conclusies, de werkwijze omvattende het in de toegangspoort aanbrengen van de kap en het vormen van een interne afdichting waarbij het kapafdichtoppervlak en het poortafdichtoppervlak met elkaar in contact zijn.

14. Kap voor een drukvat, omvattende:
- een binnenkapeinde,
- een uitsparing verschaft in het binnenkapeinde, zodat een axiale uitbreiding is gevormd, en
- een kapafdichtoppervlak verschaft bij de axiale uitbreiding.

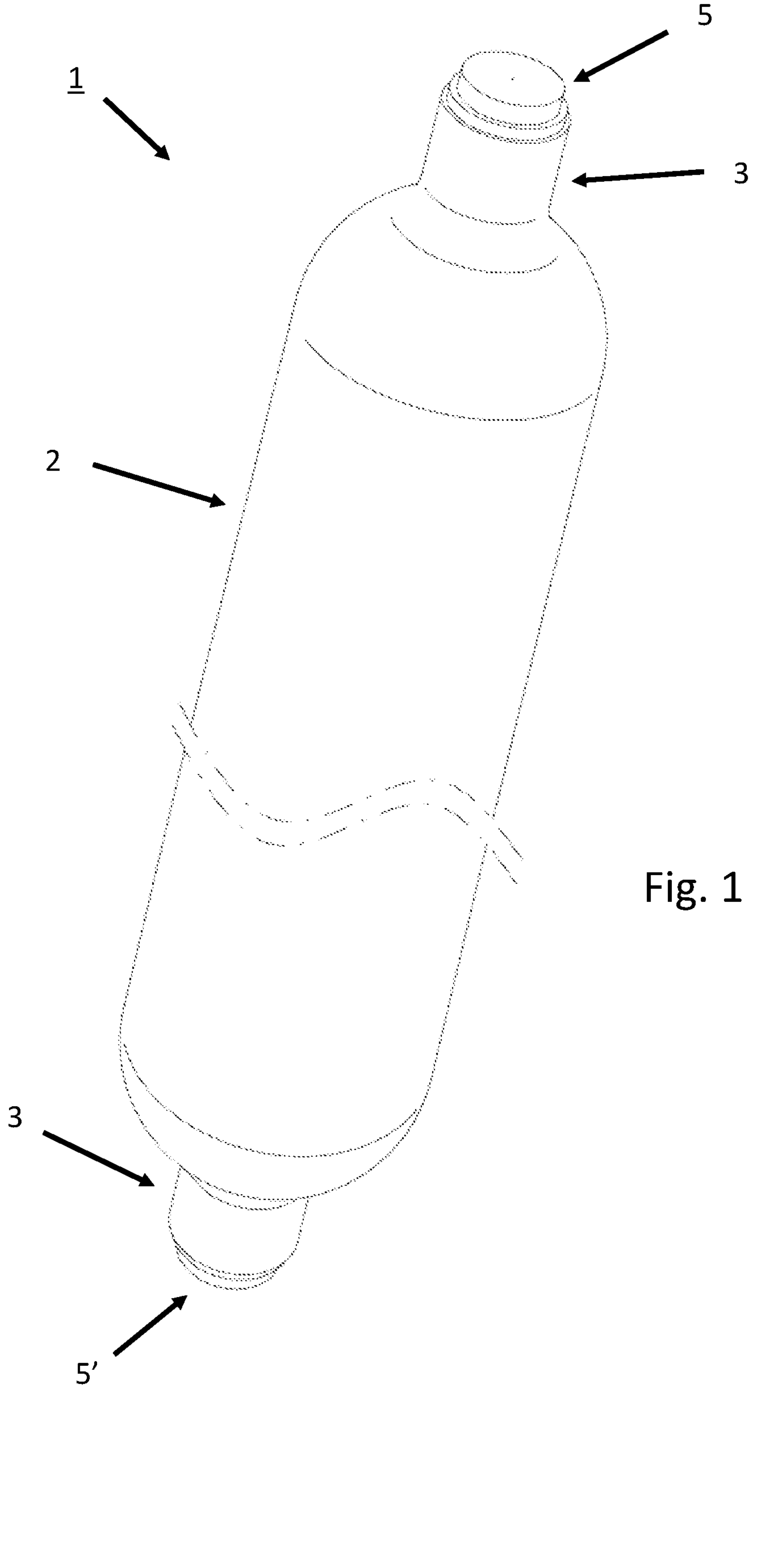


Fig. 1

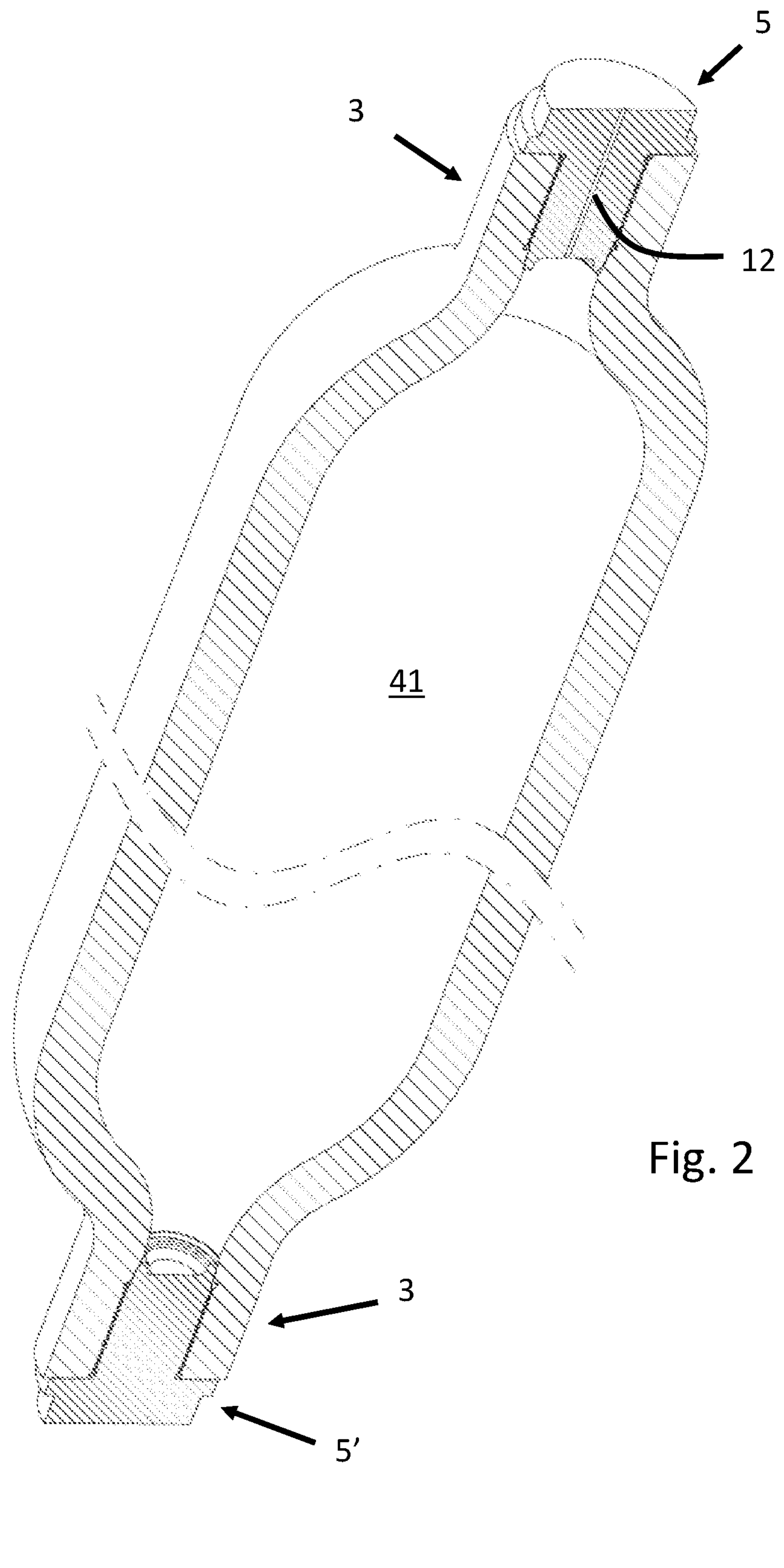


Fig. 2

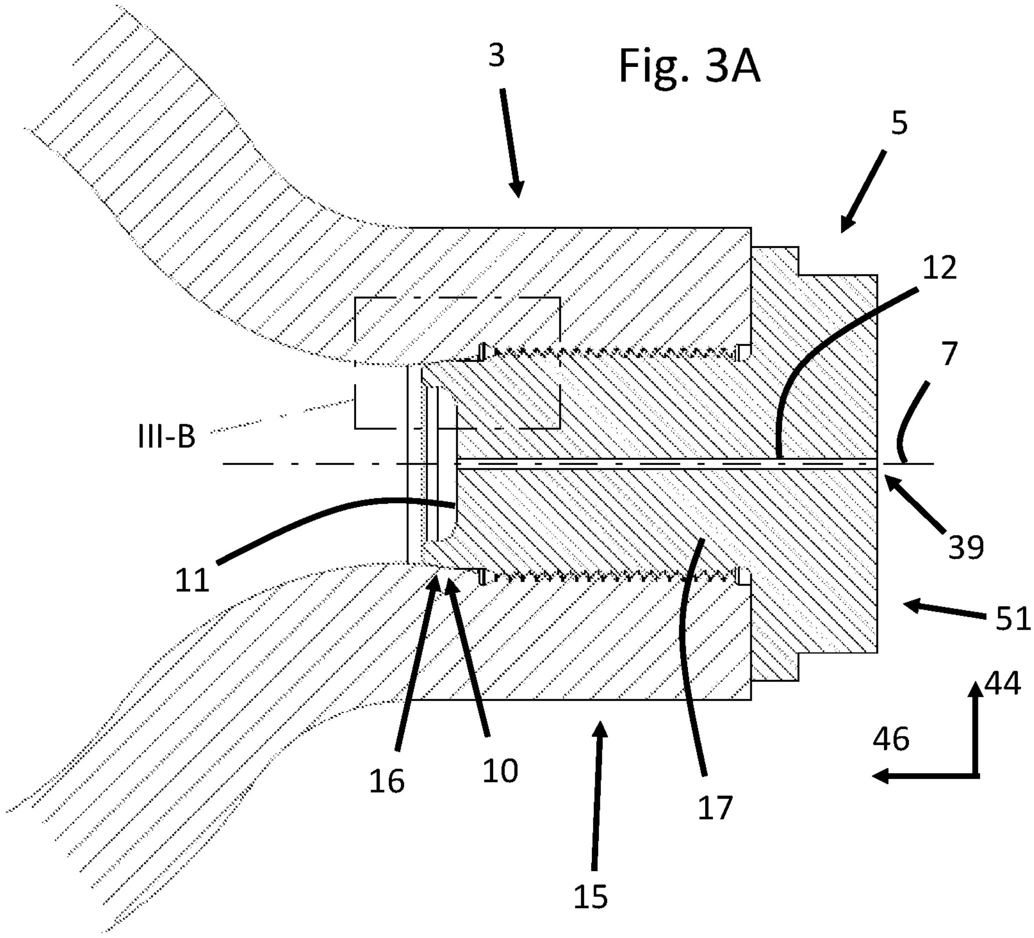


Fig. 3A

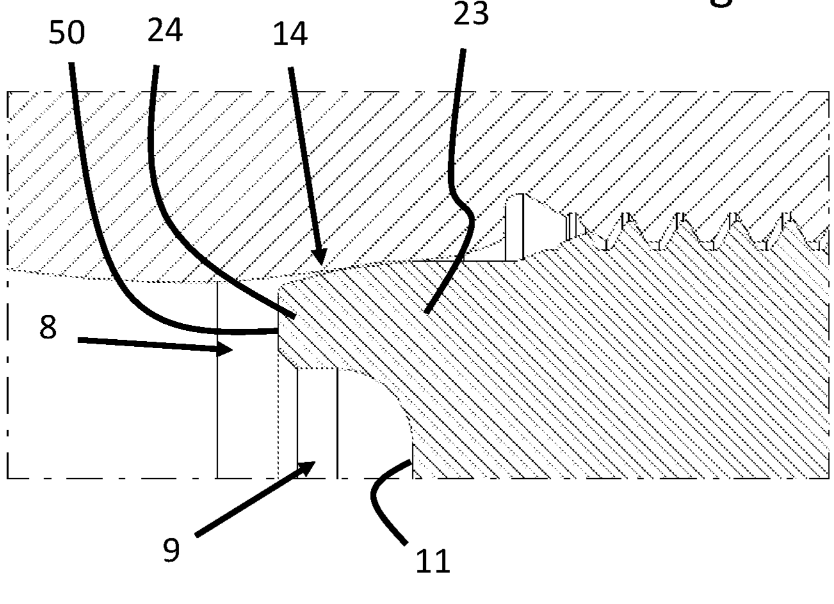
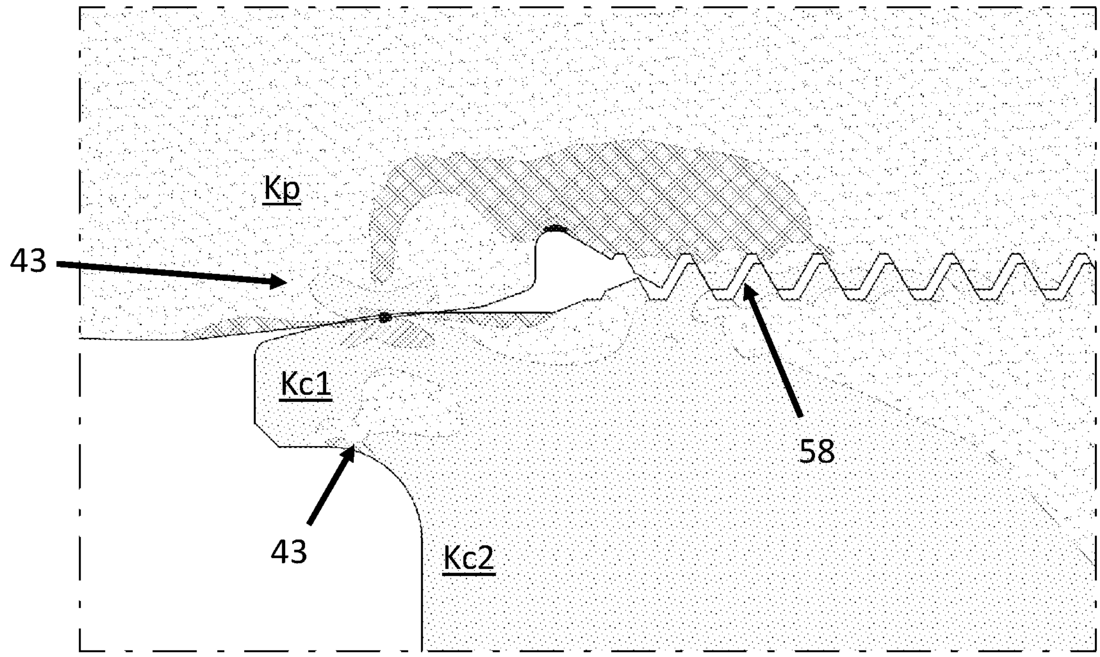


Fig. 3B

Fig. 3C



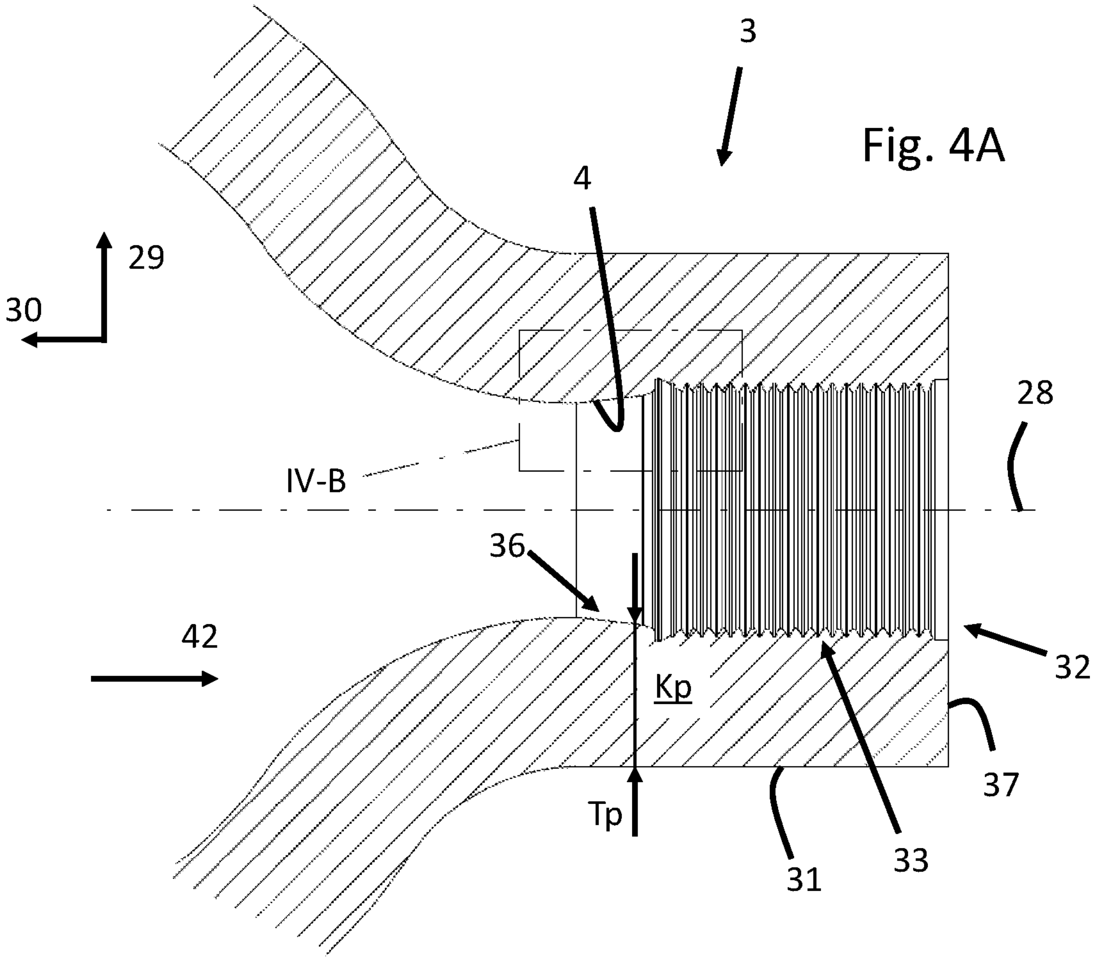


Fig. 4A

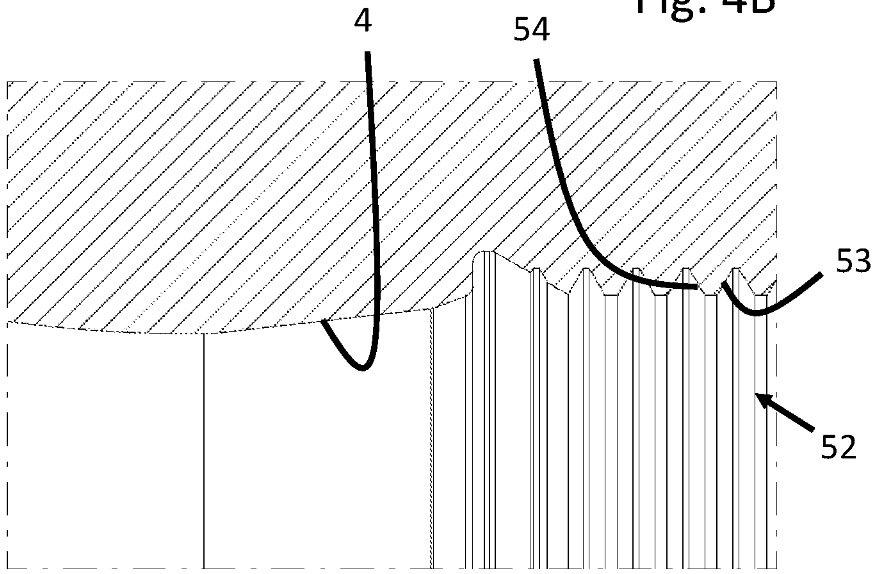
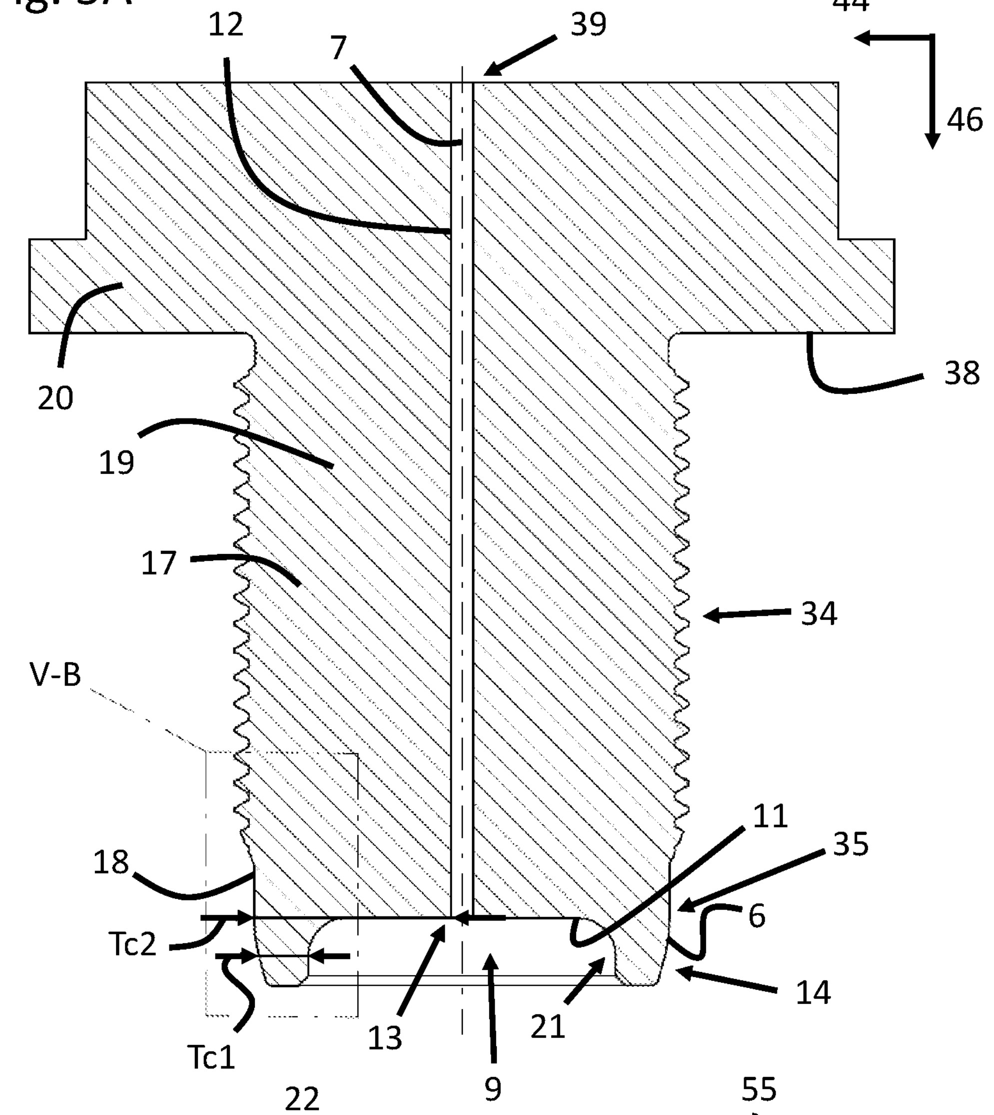


Fig. 4B

Fig. 5A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Tc1
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21
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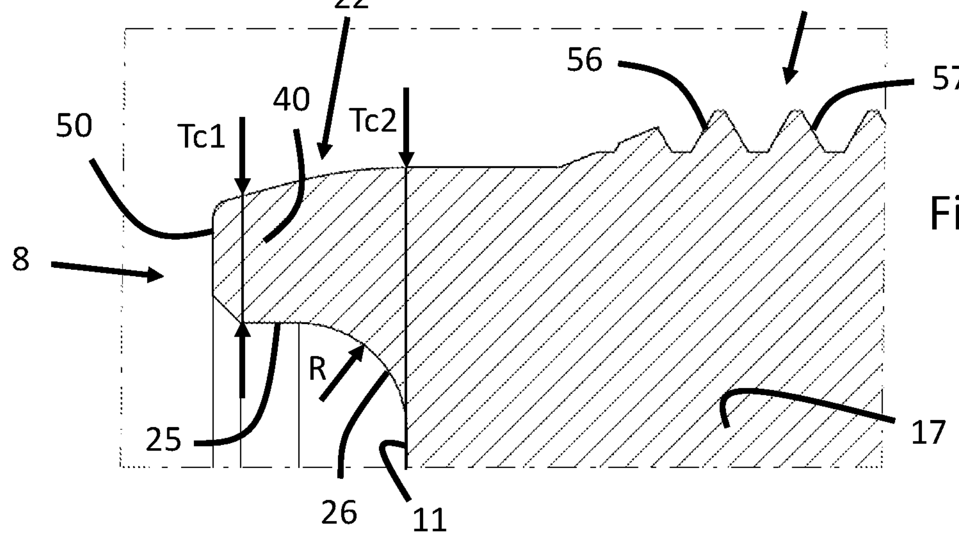
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Tc1
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Fig. 5B

Fig. 6

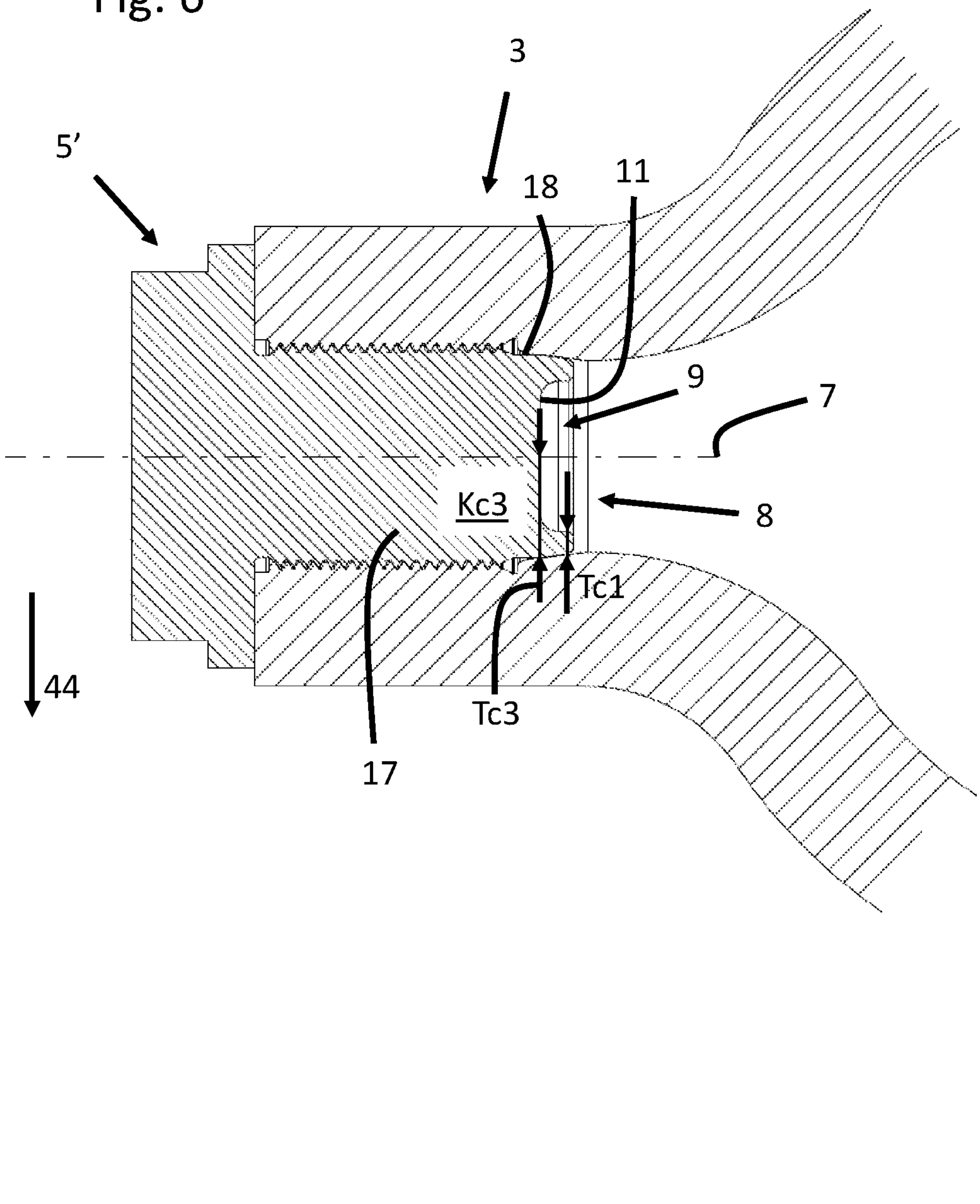
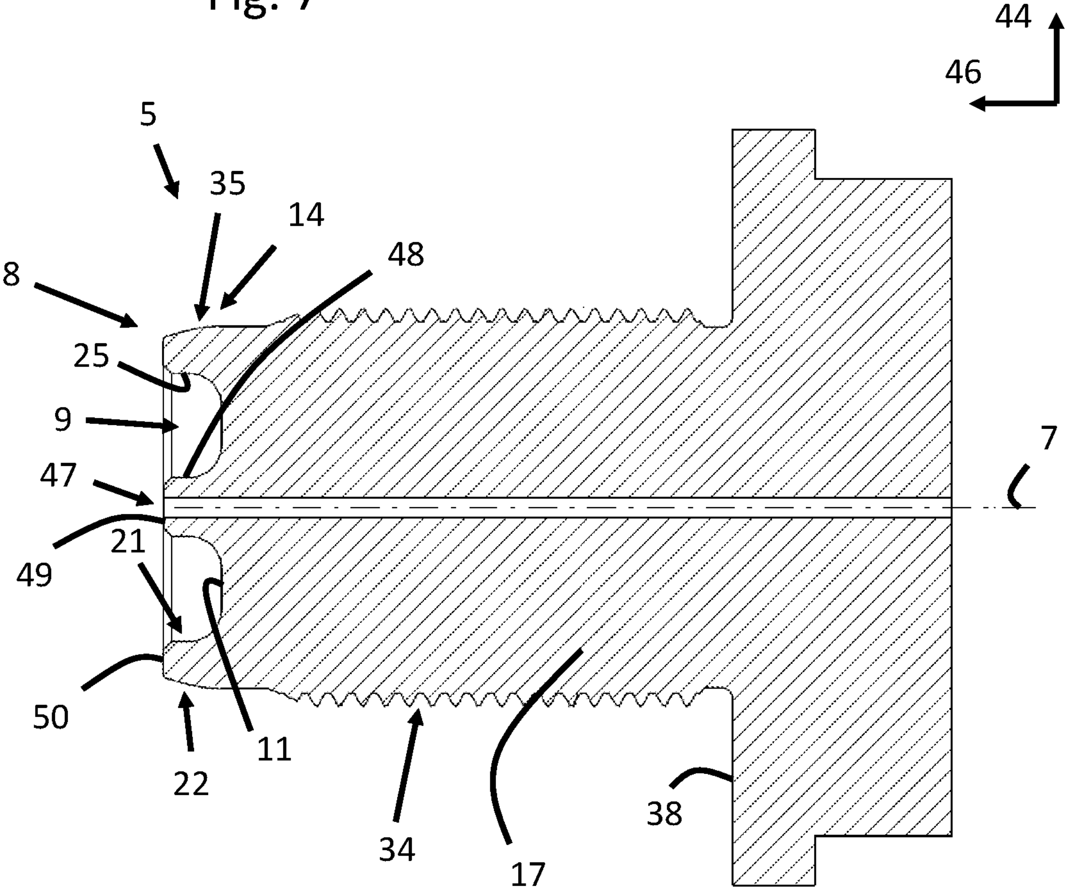


Fig. 7



SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	**KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE**
Nederlands aanvraag nr. **2034319**	Indieningsdatum **10-03-2023**
	Ingeroepen voorrangsdatum
Aanvrager (Naam) **Tenaris Connections B.V.**	
Datum van het verzoek voor een onderzoek van internationaal type **13-05-2023**	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr. **SN83823**

I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)	
Volgens de internationale classificatie (IPC) **Zie onderzoeksrapport**	

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK	
	Onderzochte minimumdocumentatie
Classificatiesysteem	Classificatiesymbolen
IPC	**Zie onderzoeksrapport**
Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen	

III.	☐	**GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES**	(opmerkingen op aanvullingsblad)
IV.	☐	**GEBREK AAN EENHEID VAN UITVINDING**	(opmerkingen op aanvullingsblad)

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2034319

A. CLASSIFICATIE VAN HET ONDERWERP
INV. F17C13/04
ADD.

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte miminum documentatie (classificatie gevolgd door classificatiesymbolen)
F17C

Onderzochte andere documentatie dan de mimimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)

EPO-Internal, WPI Data

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	EP 0 419 379 B1 (VALTUBES [FR]) 13 juli 1994 (1994-07-13) * figuren 6,7 * -----	1-14
X	DE 20 2009 008026 U1 (FUNCK HERBERT [DE]) 28 oktober 2010 (2010-10-28) * figuren 1-4 * -----	1-14
X A	US 8 657 145 B2 (STOBBART JOHN [GB]; VECTOR INT LTD [GB]) 25 februari 2014 (2014-02-25) * figuur 1 * -----	1,2,4,5, 7,8, 10-14 3,6,9
X	US 5 002 316 A (CHOHAN SATISH M [US]) 26 maart 1991 (1991-03-26) * kolom 4, regels 2-4; figuren 4,5 * -----	1-7, 10-14

☐ Verdere documenten worden vermeld in het vervolg van vak C.

☒ Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

° Speciale categorieën van aangehaalde documenten

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft
"D" in de octrooiaanvrage vermeld
"E" eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven
"L" om andere redenen vermelde literatuur
"O" niet-schriftelijke stand van de techniek
"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur
"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding
"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur
"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht
"&" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid	Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type
21 september 2023	
Naam en adres van de instantie European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	De bevoegde ambtenaar Papagiannis, Michail

1

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Informatie over leden van dezelfde octrooifamilie

Nummer van het verzoek om een onderzoek naar de stand van de techniek

NL 2034319

In het rapport genoemd octrooigeschrift		Datum van publicatie	Overeenkomend(e) geschrift(en)			Datum van publicatie
EP 0419379	B1	13-07-1994	AT	E108531	T1	15-07-1994
			DE	69010603	T2	01-12-1994
			EP	0419379	A1	27-03-1991
			FR	2652145	A1	22-03-1991
			WO	9104441	A1	04-04-1991
DE 202009008026	U1	28-10-2010	GEEN			
US 8657145	B2	25-02-2014	GEEN			
US 5002316	A	26-03-1991	AT	E105928	T1	15-06-1994
			AU	626393	B2	30-07-1992
			BR	9001272	A	26-03-1991
			CA	2012494	A1	20-09-1990
			DE	69008908	T2	20-10-1994
			DK	0389250	T3	20-06-1994
			EP	0389250	A1	26-09-1990
			ES	2053103	T3	16-07-1994
			JP	H0656228	B2	27-07-1994
			JP	H02278094	A	14-11-1990
			KR	900014806	A	25-10-1990
			MX	174388	B	12-05-1994
			SG	16195	G	18-08-1995
			US	5002316	A	26-03-1991

WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
SN83823	10.03.2023		NL2034319
International Patent Classification (IPC) INV. F17C13/04			
Applicant Tenaris Connections B.V.			

This opinion contains indications relating to the following items:

- ☒ Box No. I — Basis of the opinion
- ☐ Box No. II — Priority
- ☐ Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV — Lack of unity of invention
- ☒ Box No. V — Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI — Certain documents cited
- ☒ Box No. VII — Certain defects in the application
- ☒ Box No. VIII — Certain observations on the application

	Examiner
	Papagiannis, Michail

WRITTEN OPINION

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.
2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application, this opinion has been established on the basis of a sequence listing:

   a. ☐ forming part of the application as filed.

   b. ☐ furnished subsequent to the filing date for the purposes of search,

   ☐ accompanied by a statement to the effect that the sequence listing does not go beyond the disclosure in the application as filed.

3. ☐ With regard to any nucleotide and/or amino acid sequence disclosed in the application, this opinion has been established to the extent that a meaningful opinion could be formed without a WIPO Standard ST.26 compliant sequence listing.
4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes:	Claims	
	No:	Claims	1-14
Inventive step	Yes:	Claims	
	No:	Claims	1-14
Industrial applicability	Yes:	Claims	1-14
	No:	Claims	

2. Citations and explanations

see separate sheet

Box No. VII Certain defects in the application

see separate sheet

Box No. VIII Certain observations on the application

see separate sheet

Re Item V

1 Reference is made to the following documents:

D1	EP 0 419 379 B1 (VALTUBES [FR]) 13 juli 1994 (1994-07-13)
D2	DE 20 2009 008026 U1 (FUNCK HERBERT [DE]) 28 oktober 2010 (2010-10-28)
D3	US 8 657 145 B2 (STOBBART JOHN [GB]; VECTOR INT LTD [GB]) 25 februari 2014 (2014-02-25)
D4	US 5 002 316 A (CHOHAN SATISH M [US]) 26 maart 1991 (1991-03-26)

2 The subject matter of independent **claim 1 is not novel**, because D1 discloses all features of claim 1.

2.1 D1 *(see figures 6, 7)* discloses a pressure vessel *(reference number 61 and column 7, line 35)* for storing a pressurized fluid, such as hydrogen *(column 1, line 14)*, the pressure vessel comprising:

- a shell *(62)* comprising an access port *(opening of the tube 62)* provided with a port sealing surface *(figure 7, reference number 73 and column 12, lines 47-48)*, and
- a cap *(69 and 71)* provided with a cap sealing surface *(74)* and defining a longitudinal axis *(X3)*,

wherein:

- the access port and the cap are configured to receive and retain the cap in the access port *(see figure 6)*,
- wherein the cap sealing surface and the port sealing surface are in contact with each other to form an internal seal *(column 12, lines 47-48)*,
- the cap comprises an inner cap end *(68)*,
- a recess *(figure 7, recess on the upper surface of 69)* is provided in the inner cap end such that an axial extension *(67)* is formed, and
- the cap sealing surface *(74)* is provided at the axial extension.

3 The subject-matter of independent claim 1 is not novel also when considering documents D2-D4 (see relevant figures/passages cited in the search report).

3.1 It seems that the caps of D1, D3 and D4 require two parts to function, e.g. parts 69 and 71 in D1, which are not integral. However, D1 is still relevant for claim 1, even if only part 69 were considered to be the cap. Since the wording of independent claim 1 allows such a broad interpretation, the combination of 69 and 71 will be considered for the analysis of the dependent claims in point 6 below.

3.2 Based on a broad interpretation of claim 1 the dome portion 1 of D2 was seen as an integral cap, even if it is not attached to the neck of the tank, as is the case in the application.

4 The subject matter of the corresponding independent method claim 13 is also not new, because it defines a method, with steps which correspond to the features of the device of claim 1.

5 The subject matter of independent device claim 14 is not new, because claim 1 comprises all the features of claim 14, thus, the argumentation in point 2.1 above applies also for claim 14 mutatis mutandis.

6 The subject-matter of the following dependent claims is also not new since the additional features of these claims are also shown in D1. In brief and when considering D1:
Claims 2, 5: see figures 6, 7, areas of 67, 74.
Claim 3: see passage mentioned in column 13, lines 13-16. The only possible position of this passage is to be radially spaced from the axial extension 67.
Claim 4: see figure 7, cap extension thickness= radial thickness of area 67 and cap body thickness= radial thickness of area 69, with or without the passage of claim 3.
Claim 6: see figure 6, area 68
Claim 7: this axis of the port appears to coincide with the axis of the cap in the application, which is also the case in D1.
Claim 8: column 12, lines 35-39.
Claim 9: figure 6, reference number 70.
Claims 10, 12: figures 6, 7 include only a metal to metal seal.
Claim 11: a broad interpretation has to be adapted for the toroidal geometry, since such a shape was not found in the application. Thus, D1 can be seen as including a toroidal geometry.

Re Item VII

7 Independent claims 1, 13, 14 are not in the two-part form.

8 The features of the claims are not provided with reference signs placed in parentheses.

9 D1-D4 should be acknowledged in the description.

Re Item VIII

10 Device claims 1 and 14 have been drafted as separate independent claims. This formulation is not considered to be concise, as claim 14 repeats subject-matter that has already been included in claim 1. In fact, claim 1 has all the features of claim 14 and as a result claim 1 appears to be in fact a dependent claim.

10.1 It is noted that the requirement that the claims should be clear applies to individual claims and also to the claims as a whole, in other words the claim 1 and 14 should not only be considered individually when examining clarity.