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(73) Patenthaver:
HYET HOLDING B.V., Westervoortsedijk 71 K 6827 AV Arnhem, Holland

(72) Opfinder:
Albert BOS, --, 6827 AV Arnhem, Holland
Adriaan Rombout SWANBORN, --, 6827 AV Arnhem, Holland

(74) Fuldmægtig:
Zacco Denmark A/S, Arne Jacobsens Allé 15, 2300 København S, Danmark

(54) Titel: **Solid-state compressor**

(56) Fremdragne publikationer:
US 2011/0081591 A1
US 5187025 A
JP 2008123957 A
US 2017/0317373 A1
JP 2006185613 A

(57) Sammendrag:
The present invention relates to a solid state hydrogen compressor, comprising at least one membrane fixed between two porous electrodes, together forming a membrane electrode assembly, a pair of cell plates or bipolar plates, between which the membrane electrode assembly is clamped, wherein the membrane has a larger area than the porous electrodes and protrudes outside an area of the porous electrodes; and the cell plates have a larger area than the membrane and protrude outside an area of the membrane two insulating gaskets each surrounding one of the porous electrodes covering the part of the membrane that protrudes outside the region of the electrodes and protruding outside the area of the membrane, further comprising a reinforcement layer, arranged between the insulating gaskets, outside the area of the electrodes.

Fortsættes...

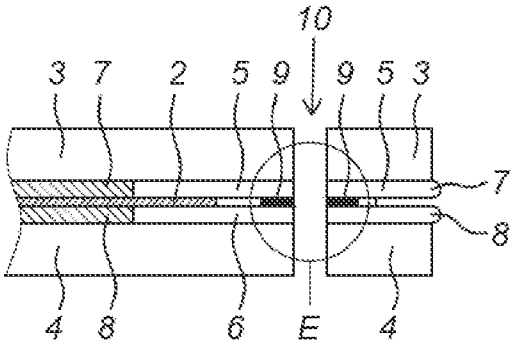

Fig. 5b

Solid-state compressor

The present invention relates to a solid state compressor, in particular a solid state hydrogen compressor, and more in particular to the sealing of such compressor.

The core of a solid-state hydrogen compressor is a membrane which is normally fixed between two porous electrodes, together forming a membrane electrode assembly (MEA). The electrodes are porous to allow gases and fluids to pass to and from the membrane, and electrically conductive to allow a current to be affected.

The membrane electrode assemblies are fixed between cell plates (also called so-called bipolar plates) which are complex structures that have multiple functions: they mechanically support the membrane electrode assemblies, allow current to pass through and supply and divert gases and water to and from the membrane electrode assembly. The combination of membrane electrode assembly and surrounding bi-polar or cell plates is usually called a cell.

A solid-state compressor is normally composed of multiple cells to achieve enough capacity (total membrane surface area). To be cost effective and to allow current to be passed through the cells without wiring, the cells are stacked in series and clamped between end flanges. This is well known from the field of fuel cell stacks, which are stacked in a similar manner and for the same purpose.

Contrary to fuel cell stacks which are normally operated at a few bars pressure, in the case of a hydrogen compressor, the end flanges and cell plates need to provide sufficient mechanical strength and stability to contain the operating pressures of the compressed gas which can exceed 1000 bar.

In fuel cell stacks the membrane electrode assemblies are clamped between the bi-polar plates and have a non-conducting edge (the border/gasket) which prevents current from passing directly from electrode to electrode around the membrane electrode assembly (an electrical short circuit) and often also provide a mechanism of sealing at the same time. Sometimes the sealing function is provided by other parts such as gaskets.

An example of a cell stack used for an electrochemical compressor wherein gaskets are used for sealing is described in US2011081591 A1. The gaskets described herein are formed from meltable polymers or rubbers which can be processed thermally.

In the case of high-pressure solid-state compression stacks the same insulation and sealing functions need to be performed as with fuel cells. Both functions can be conveniently performed by employing an insulating polymer (film). The polymer (film) can either 'wedge' the membrane of the membrane electrode assembly, or else be employed on one or both sides of the membrane and forming an insulating 'gasket'.

By exerting a mechanical (vertical) pressure on this border polymer, the sealing can be accomplished and a mechanical pressure higher than the compression pressure is applied. In some cases this may be in excess of 700 bar or 1000 bar. However, at these very high sealing pressures the polymer and/or polymer and the membrane may be plastically deformed and forced either out from between the bi-polar plates or into orifices needed for passing through gasses and or liquids to the membrane electrode assembly, or the orifices of the cooling fluids.

The amount of deformation depends on the characteristics of the polymeric materials and their thicknesses. The thicker the layers and the more plastically deformable, the easier it becomes for the materials to 'flow'. In any sub-volume of a polymer the molecular chains have some degree of freedom to move or stretch. The thinner a polymer sheet is, the less this flexibility allows the core part of the polymer sheet to move/deform laterally.

Another way to provide enough sealing with tolerable lateral deformation is to make the border very wide. This increases the ratio of the lateral part of the polymer to its thickness, however, this increases the cost and size of the peripheral structures.

It is a goal of the present invention to take away the disadvantages of the prior art solid state compressors, or at least to provide a useful alternative. The invention thereto proposes a solid state hydrogen compressor, comprising at least one membrane fixed between two porous electrodes, together forming a membrane

electrode assembly, a pair of cell plates or bipolar plates, between which the membrane electrode assembly is clamped, wherein the membrane has a larger area than the porous electrodes and protrudes outside an area of the porous electrodes; and the cell plates have a larger area than the membrane and protrude outside an area of the membrane, two insulating gaskets, each surrounding one of the porous electrodes, covering the part of the membrane that protrudes outside the region of the electrodes; and protruding outside the area of the membrane, and a reinforcement layer, arranged between the insulating gaskets, outside the area of the electrodes.

The reinforcement layer may be a high pressure sealing, which is a sealing that is capable of withstanding a pressure up to 50-1000 bar, which provides insulation and also results in borders of manageable size.

The reinforcement layer may for instance surround the membrane, and thus be located at the place where the gaskets extend beyond the surface of the membrane.

Preferably the reinforcement layer fills the area between the insulating gaskets around the membrane. An even distribution of the forces exerted on the gasket and the reinforcement layer is herewith obtained.

The reinforcement layer may be made of an insulating material such as Kevlar, which has the advantage that the risk of an electric shortcut is reduced, but it may also be metal layer, which may be beneficial because of its high strength.

In general, the solid state hydrogen compressor according to the present invention may have a round cross section, wherein the membrane, the electrodes and the cell plates all have round cross sections and the gaskets and the reinforcement layer have ring shaped cross sections. This leads to a robust construction.

The reinforcement layer may be within the region of the bipolar plates. So it may be kept just as small as necessary, not extending outside the stack forming the hydrogen compressor. For an optimal insolation, the gasket may extend beyond the

membrane on either side of said membrane in the direction facing away from the porous electrodes.

The gasket may be made from a polymer, which may a regular polymer used in hydrogen compressor according to the state of the art, be it that the reinforcement layer allows the gasket to be thinner, and thus have a smaller risk of deformation.

Alternatively, multiple reinforcement parts may be applied, in particular surrounding channels in the solid state hydrogen compressor. These channels may be for coolant or for a gas to be compressed, such as hydrogen.

A reinforcing structure may also be embedded in the polymer border material, most conveniently by laminating. Preferably here also a metal reinforcement may be used, but other reinforcing materials such as Kevlar etc. may be used.

This reinforcing structure prevents the outward deformation of the polymer by allowing thinner polymer layers that can withstand more lateral shear force. Ideally this structure is of a suitable thickness and in combination with the polymer film make the border of a thickness in the same range of the membrane electrode assembly itself so that flat bi-polar plates can be used.

The thickness of the reinforcement may be between 1 and 200 um, while the thickness of the bipolar plates may be between 200 and 5000 um.

As the reinforcing structure is insulated between the polymer sheets, it may be of a conducting material as the polymer provides the insulating feature, but an insulator may be applied too, and even be preferred.

Alternatively, for intermediate pressure systems, if the membrane itself forms part of the border, smaller reinforcing structures may be embedded around the smaller orifices to prevent membrane and/or polymer to deform into the orifices.
The invention will now be elucidated into more detail, with reference to the following figures, wherein:

- Figure 1 shows a fuel cell according to the state of the art;
- Figure 2 shows a stack of fuel cells according to the state of the art;

- Figure 3a shows a detail of a first embodiment of a stack of fuel cells according to the state of the art;
- Figure 3b shows a detail of a second embodiment of a stack of fuel cells according to the state of the art;
- Figure 4a shows a first detail of a problem associated with the state of the art;
- Figure 4b shows a second detail of a problem associated with the state of the art;
- Figures 5a and 5b show details of the present invention.

Figure 1 shows a fuel cell according to the state of the art. The cell comprises a membrane 2, clamped in between electrodes 31, 41, formed by graphite blocks. In between the membrane and the respective electrodes, gas diffusion backings 71, 81 are present, with a smaller area than the area of the membrane 2 and the electrodes 31, 41. The diffusion backings are surrounded by Teflon masks 51, 61.

Figure 2 shows a stack 101 of multiple fuel cells 1 according to the state of the art. The stack 101 comprises multiple fuel cells 1 as shown on figure 1, separated by cooling plates 11, 12, 13, 14. The fuel cells are clamped in between end plates 15 and 16.

Figure 3a shows a detail in a first embodiment of a fuel cell 1 from figure 1 in a stack of fuel cells, as shown in figure 2. In the figure it is visible that the membrane 2 extends beyond the electrodes 7, 8. Where it extends, it is clamped in between gaskets 5, 6. The gaskets are larger than the area over which the membrane 2 extends beyond electrodes 7, 8 and engage each other outside the membrane area. This is indicated with region A.

Figure 3b shows a detail in a second embodiment of a fuel cell 1 from figure 1 in a stack of fuel cells 101, as shown in figure 2. In the figure it is visible that the membrane 2 extends beyond the electrodes 7, 8. Where it extends, it is clamped in between Teflon masks 5, 6. The gaskets are just as large as the area over which the membrane 2 extends beyond electrodes 7, 8 and do in this embodiment not engage each other outside the membrane area.

Figure 4a shows a problem associated with the a fuel cell 1 according to the state of the art, in a stack of fuel cells 101 as shown in figure 2, once a mechanical sealing pressure is applied on the cell stack 101. It is visible in the region indicated with B that the gaskets 5 and 6 have shifted in a direction perpendicular to the sealing pressure, both with a different amount. The region indicated with C shows the effect, both masks are pressed out of the stack, also to a different extend.

Figure 4b shows a second detail of a problem associated with the state of the art, when gaskets 5, 6 are in the vicinity D of a through hole 10 through the cell plates 3, 4, for coolant or for hydrogen for instance. The force for assembling the compressor forces the gaskets 5, 6 into the through hole 10, which may then be unintendedly be blocked or partly be blocked.

Figure 5a shows a detail of the present invention. As can be seen in the figure, the membrane 2 extends outside the electrode 7 and 8. Where the membrane extends outside the electrodes, gaskets 5 and 6 are placed between the cell plates 3, 4 and the membrane 2. Where the membrane stops, a reinforcement 9 is placed between the gaskets 5 and 6. The reinforcement 9 has a similar thickness to that of the compressed membrane 2, while the gaskets 5 and 6 have similar thicknesses as the electrodes. As a result, the gaskets remain at their intended locations.

Figure 5b shows a similar configuration, with a through hole at location E. Around the through hole a small reinforcement is applied, with a corresponding hole 10, to avoid the gaskets 5 and 6 to be pressed into the through hole 10. In a configuration like this, several reinforcements may be applied.

The examples given are exemplary only and do in no way limit the scope of the present invention, as defined in the following claims.

Patentkrav

1. Faststofbrintkompressor, der omfatter:

- mindst én membran, der er er fastgjort mellem to porøse elektroder, der sammen danner en membranelektrodesamling;
- et par celleplader eller bipolære plader, hvorimellem membranelektrodesamlingen er fastspændt;

hvor

- membranen har et større område end de porøse elektroder og rager uden for et område af de porøse elektroder; og
- cellepladerne har et større område end membranen og rager uden for et område af membranen;

- to isolerende pakninger,
  - der hver især omgiver en af de porøse elektroder;
  - dækker den del af membranen, der rager uden for elektrodernes område; og
  - rager uden for membranens område;

kendetegnet ved

et forstærkningslag, der er anbragt mellem de isolerende pakninger, uden for området af elektroderne, hvor forstærkningslaget har en lignende tykkelse som tykkelsen af den fastspændte membran, og hvor pakningerne har de lignende tykkelser som tykkelserne af elektroderne.

2. Faststofbrintkompressor ifølge krav 1, hvor forstærkningslaget omgiver membranen.

3. Faststofbrintkompressor ifølge krav 1, hvor forstærkningslaget udfylder området mellem de isolerende pakninger omkring membranen.

4. Faststofbrintkompressor ifølge krav 1 eller 2, hvor forstærkningslaget er et metallag.

5. Faststofbrintkompressor ifølge et hvilket som helst af de foregående krav, hvor pakningen er fremstillet af en polymer.

6. Faststofbrintkompressor ifølge et hvilket som helst af de foregående krav, hvor pakningen er fremstillet af kevlar.

7. Faststofbrintkompressor ifølge et hvilket som helst af de foregående krav, med et rundt tværsnit, hvor membranen, elektroderne og cellepladerne har runde tværsnit, og pakningerne og forstærkningslaget har ringformede tværsnit.

8. Faststofbrintkompressor ifølge krav 1, hvor forstærkningslaget er begrænset til det område, der er dækket af de bipolære plader.

9. Faststofbrintkompressor ifølge krav 1 eller 2, hvor pakningen strækker sig ud over membranen på begge sider af membranen i den retning, der vender væk fra de porøse elektroder.

10. Faststofbrintkompressor ifølge krav 1, som omfatter flere forstærkningslag, der omgiver kanaler i faststofbrintkompressoren.

11. Faststofbrintkompressor ifølge et hvilket som helst af de foregående krav, hvor forstærkningslaget er en højtryksforsegling, der kan modstå et tryk på op til 1000 bar.

12. Faststofbrintkompressor ifølge et hvilket som helst af de foregående krav, hvor den forstærkende struktur er indlejret i et polymerrandmateriale, især ved laminering.

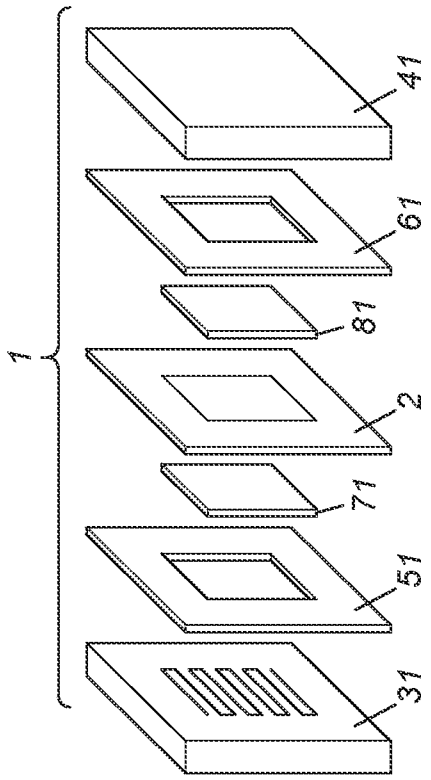

Fig. 1

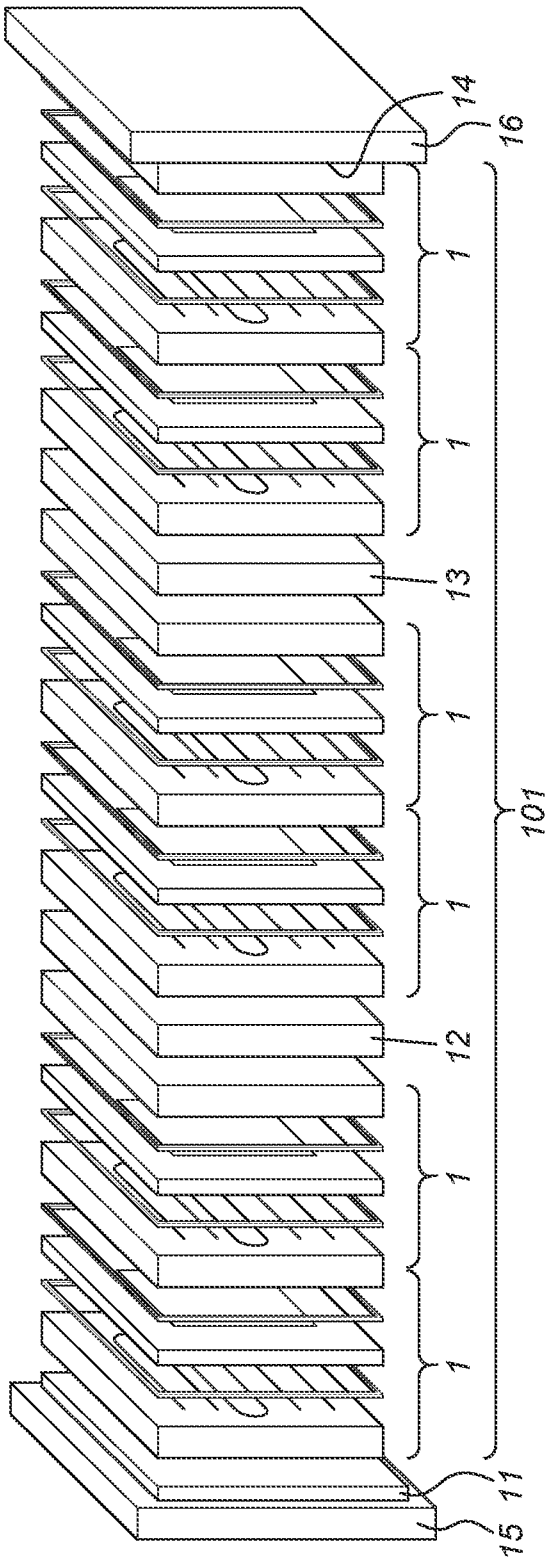

Fig. 2

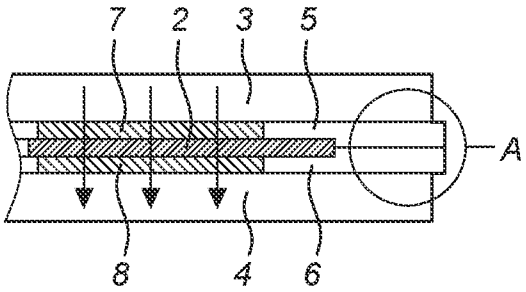

Fig. 3a

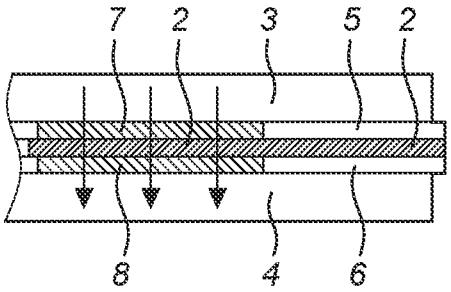

Fig. 3b

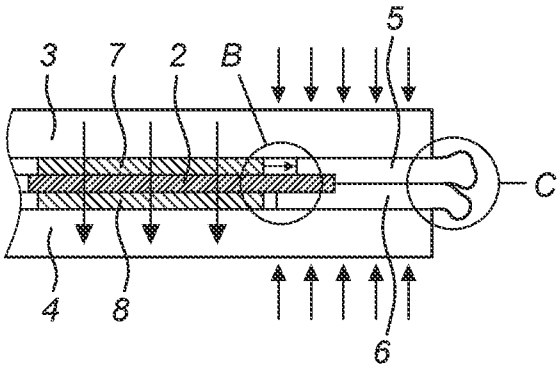

Fig. 4a

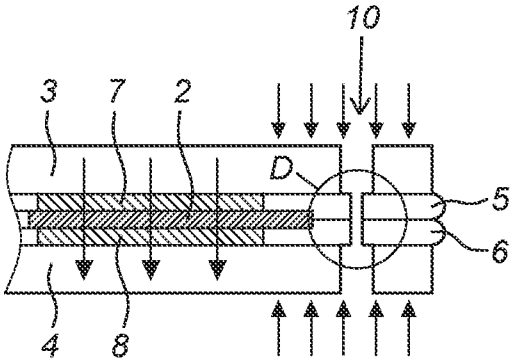

Fig. 4b

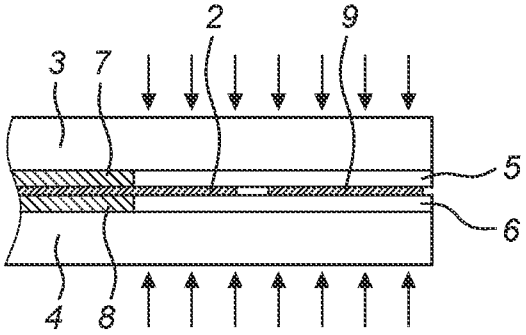

Fig. 5a

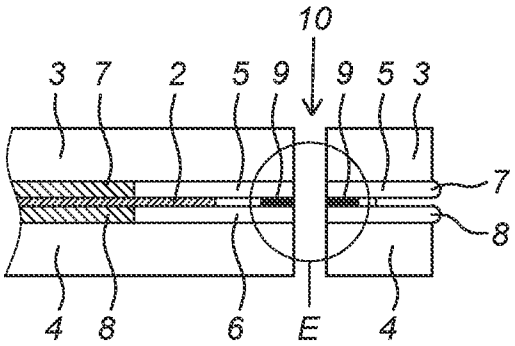

Fig. 5b

DANISH PATENT AND TRADEMARK OFFICE

SEARCH REPORT - PATENT	Application No. PA 2021 70307

1. ☐ Certain claims were found unsearchable (See Box No. I).

2. ☐ Unity of invention is lacking prior to search (See Box No. II).

A. CLASSIFICATION OF SUBJECT MATTER

C25B 1/04 (2021.01), C25B 9/05 (2021.01), C25B9/23 (2021.01), C25B 9/60 (2021.01), C25B 11/02 (2021.01), C25B 13/02 (2006.01)

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

PCT-minimum documentation searched (classification system followed by classification symbols)

IPC & CPC: C25B

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

Electronic database consulted during the search (name of database and, where practicable, search terms used)

EPODOC, WPI, FULL-TEXT: ENGLISH

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant for claim No.
Y	US 2011/0081591 A1 (SCHERER JOACHIM et al.) 2011.04.07 Paragraphs [0001], [0272], [0317] Figure 5	1-9, 11
Y	US 5187025 A (KELLAND JAMES W et al.) 1993.02.16 Column 1, lines 6-10 Column 3, lines 1-15; 38-50 Figure 2	1-9, 11
A	JP 2008123957 A (MITSUBISHI ELECTRIC CORP) 2008.05.29 Machine translation of paragraphs [0006], [0043]-[0046] Figure 3	1-9, 11, 12

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

* Special categories of cited documents:	"P" Document published prior to the filing date but later than the priority date claimed.
"A" Document defining the general state of the art which is not considered to be of particular relevance.	"T" Document not in conflict with the application but cited to understand the principle or theory underlying the invention.
"D" Document cited in the application.	"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.
"E" Earlier application or patent but published on or after the filing date.	"Y" Document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"L" Document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified).	"&" Document member of the same patent family.
"O" Document referring to an oral disclosure, use, exhibition or other means.	

Danish Patent and Trademark Office
Helgeshøj Allé 81
DK-2630 Taastrup
Denmark

Tel.: +45 4350 8000

Date of completion of the search report
02 March 2022

Authorized officer
Peter Philip Holck
Tel.: +45 43 50 85 58

SEARCH REPORT - PATENT		Application No. PA 2021 70307
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant for claim No.
A	US 2017/0317373 A1 (STAHL PETER et al.) 2017.11.02 Paragraphs [0088]-[0105] Figure 2	1-9, 11, 12
A	JP 2006185613 A (NISSAN MOTOR) 2006.07.13 Machine translation of paragraphs [0040]-[0045] Figure 8	1-9, 11, 12

SEARCH REPORT - PATENT	Application No. PA 2021 70307

Box No. I Observations where certain claims were found unsearchable

This search report has not been established in respect of certain claims for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched, namely:

2. ☐ Claims Nos.:
   because they relate to parts of the patent application that do not comply with the prescribed requirements to such an extent that no meaningful search can be carried out, specifically:

3. ☐ Claims Nos.:
   because of other matters.

Box No. II Observations where unity of invention is lacking prior to the search

The Danish Patent and Trademark Office found multiple inventions in this patent application, as follows:

SEARCH REPORT - PATENT	Application No. PA 2021 70307

SUPPLEMENTAL BOX

Continuation of Box [.]