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(54) Benævnelse: **Tårn til et vindenergianlæg samt fremgangsmåde til rejsning heraf**

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Description

The present invention relates to a tower for a wind energy facility, which has a tower section, which has an inwards-protruding foot flange on its end pointed towards the foundation. The invention also relates to a method for erecting a tower for a wind energy facility.

The towers for wind energy facilities according to the invention comprise towers, which are designed for onshore or offshore erecting. In the case of offshore wind energy facilities, the construction anchored in the sea floor, on which the tower is erected, is referred to below as the foundation.

A method for the fastening of elements within a tower of a wind energy facility became known from EP 1 933 029 A1. The tower consists of different sections of metal, wherein the elements provided in it are fastened on auxiliary supports. The auxiliary supports should be fastened on each tower section such that the material is not weakened. In order to avoid a weakening of the material, double-T supports are fastened on an upper flange and a lower flange of the tower section and progress parallel to the tower walls. A fixed bearing, on which the supports are fastened, is provided on the upper flange, while a loose bearing, which allows a shifting of the support in the tower length direction, is provided on the lower flange.

A tower for a wind energy facility, in which a power module is arranged on a supporting construction, is known from US 2007/0187956 A1. The supporting construction is supported on the foundation of the wind energy facility.

A wind energy facility tower became known from DE 20 2010 007 565 U1, which has a tubular tower section, on the upper flange of which internal structures of the tower can be hung.

A wind energy facility as well as a method for erecting the same became known from WO 2006/056196, in which stackable structures are stacked on top of each other, wherein the bottommost structures sit directly on the foundation.

A wind energy facility with a lower tower section became known from WO 2010/103114 A1, in which an electrical apparatus for the wind energy facility is preassembled. During the preassembly, the electrical units, such as e.g. the transformer, control cabinet, converter, emergency switch and the like, are fastened on the tower walls.

A cable support, in particular for supporting the generator cable of a wind energy facility, became known from DE 10 2005 049 289 A1, which has a support ladder made up of several individual ladders. The individual ladders are each mounted separately and hung in the tower as hanging ladders.

A tower for a wind energy facility became known from WO 2008/000565 A2, the structures of which are fastened in the tower sections respectively on an upper and a lower flange. The structures supporting the electrical components sit on the foundation.

A telescopically designed tower for large wind energy facilities became known from WO 02/46552 A1. During the erecting of the tower, tie rods are temporarily tensioned between the upper and lower flange of a tower section, along which the height of a further tower section can be moved.

The object of the invention is to provide a tower for a wind energy facility as well as a method for erecting the same, in which heavy electrical structures of the wind energy facility can be safely and reliably preassembled without weakening the tower walls.

According to the invention, the object is solved by a tower with the characteristics of claim 1. Preferred embodiments form the subject matters of the dependent claims.

The tower according to the invention is provided and determined for a wind energy facility. The tower has a tower section, which has an inwards-protruding foot flange on its end facing towards the foundation. The foot flange can be designed as one piece or as several pieces. Thus, foot flanges that are connected with a load-distribution plate are also foot flanges in terms of the invention. The tower installation according to the invention can be supported on the one-piece foot flange. Alternatively, the tower installation can be supported on the load-distribution plate connected with the foot flange. According to the invention, a self-supporting tower installation is provided for the tower section, which has at least three stands progressing parallel and spaced with respect to the tower wall and the stands have interconnecting cross members. The stands are preferably distributed evenly over the periphery of the foot flange, in order to form a self-supporting tower installation, which is completely supported on the foot flange. The stands are placed on the foot flange. The self-supporting tower installation is set up on the foot flange, without further connections potentially weakening the tower wall being present between the tower installation and the tower wall. The invention is based on the knowledge that even heavy components of a wind energy facility can be erected safely and reliably in the tower through a free-standing and self-supporting tower installation. Connections with an upper flange or with the tower wall, which increase the effort for the assembly of the tower installation, can be omitted in the case of the invention.

With the tower installation according to the invention, the space present in the tower section can be used optimally. Thus, for example tower installations, which are placed directly on the foundation, have a considerably smaller diameter than the tower. This is required in order to be able to move the tower installation through the inwards-facing flange of the tower section or to push the tower section over the tower installation sitting on the foundation. Through the supporting of the tower installation on the foot flange of the tower section, the tower installation can be preassembled in the tower section and the existing space can be used optimally.

In a preferred design, the ends of the stands pointing away from the foot flange are free and not connected with the tower wall. The stands are held in their position with their end-side fastenings on the foot flange solely by the cross members and can thus carry heavy loads. The use of a loose bearing, which gives sufficient play for the stands in the case of a potential deformation of the tower, can also be omitted, since the stands are only supported on the foot flange and otherwise progress freely in the tower. Structure-weakening interventions in the tower wall can be avoided.

In a further development of the invention, the cross members are connected exclusively with the stands or a different cross member and are not attached to the tower wall in any fashion.

In a preferred further development of the invention, the cross members are arranged horizontally between the stands in order to form at least one platform in the tower installation. The tower installation preferably has several platforms arranged above each other, on which the individual components can be made accessible for operating personnel.

In a particularly preferred design, a platform arranged above the foot flange is supported by short stands, which support at least one cross member of the platform on the foot flange. Particularly heavy components of the wind energy facility can be placed on this platform located near the foot flange. In addition to the short stands, this platform can also be supported on the long stands.

In a preferred further development of the invention, at least one damping element is arranged laterally between the tower installation and the inside of the tower wall. The damping element is preferably fastened on the tower installation. The damping element prevents oscillations from the tower wall, for example through operation of the wind energy facility, from being transferred to the tower installation and the components set up in it. The transfer of oscillations from the tower installation to the tower section through the damping element can also be prevented. In the case of the damping element, it should be differentiated whether it permanently establishes contact between the tower installation and the inside of the tower wall or whether it only comes in contact with the tower wall in the case of oscillations with a larger amplitude and thus prevents transfer of oscillations.

The stands are preferably designed as a T-profile or as a double-T profile. The stands have on their end pointing towards the foot flange a load-distribution plate, which is preferably equipped with bore holes, in order to connect the stands with the foot flange. Alternatively or additionally, the stands can also be equipped with a flange, via which the stands can be fastened on the foot flange. The flange can thereby lie on the flat side of the foot flange facing the tower installation or protrude over it, rest against its front surface and be fastened.

In a preferred design, the foot flange is designed as one piece with the tower wall. In this design, the foot flange simultaneously forms on its bottom side a bearing surface, with which the tower section can be placed on a foundation body, a further tower section or an adapter connecting the foundation body and the lower tower section.

In an alternative design, the foot flange provided for the support of the tower installation is designed as multiple parts and connected with the tower section via connection means. Such a foot flange can be formed for example by a load-distribution plate, which is arranged between the tower section and its support, for example a foundation body or an adapter.

The object according to the invention is also solved by a method with the characteristics from claim 14. Advantageous embodiments of the method form the subject matters of the dependent claims.

The method according to the invention is provided for erecting a tower for a wind energy facility. The provision of a tower section, which has an inwards-protruding foot flange on one end, takes place in one method step. For erecting the self-supporting tower installation in the tower section, which has at least three stands progressing parallel and spaced with respect to the tower wall and the cross members interconnecting the stands, the stands are arranged distributed over the periphery of the foot flange in a subsequent step and fastened on the foot ends on the foot flange of the tower section, so that the self-supporting tower installation sits freely supported in the tower section on the foot flange. The installation of a self-supporting and free-standing tower installation only supported on the foot flange offers the advantage that a weakening of the tower wall is avoided. In subsequent steps, the stands are connected with the cross members and the bottom plates for the formation of platforms are mounted on the cross members. The installation of components in the tower installation and the erecting of the tower for the wind energy facility with the tower section, in which the components are already installed in the tower installation, take place in further steps. The installation time, in particular for offshore towers in sea, is hereby reduced, whereby considerable cost savings are achieved in the erecting of the towers. The components are for example electrical components of the wind energy facility, which can be arranged in the foot area of the tower.

In a preferred further development of the method, a check of the installed components takes place after installation of the components in the tower installation and before erecting of the tower. In this manner, errors in the connection of the components or errors in the components themselves can be detected early. The initial elimination of errors at the site of the erecting of the tower, whether it be offshore or onshore, can be avoided.

In a preferred design, the tower section is provided upright so that the foot flange is located on the lower end of the tower section and the installation of the tower installation on the foot flange can take place in the upright tower section. The foot flange can be designed as one piece with the tower section; alternatively, it is also possible to connect for example a load-distribution plate with the tower section and to provide it as a foot flange for the supporting of the tower installation.

In a preferred embodiment, the tower section is then transported upright to the erecting location of the tower. It is hereby avoided that the free-standing tower installation is incorrectly loaded or damaged in the tower section.

The components of one or more components installed in the tower installation are preferably from the following group: generator, transformer, cabinet and converter. These can also be electrically connected with each other in the tower and can be tested fully or partially during their operation.

A preferred design of the tower according to the invention is explained in greater detail below based on an exemplary embodiment. They show in:

Fig. 1 a schematic view of a wind energy facility,

Fig. 2 a schematic view of the tower installation according to the invention in a longitudinal cut,

Fig. 3 a-c sectional representations along the lines A-A, B-B and C-C from Fig. 2,

Fig. 4 a-b a schematic view of the stands in the area of the foot,

Fig. 5 a schematic view of the stands in the area of the foot flange when using a load-distribution plate.

Fig. 1 shows a wind energy facility 1 with a tower 2 and a nacelle 4 arranged on it. The power train (not shown) of the wind energy facility, which is connected with the rotor 6, is located in the nacelle. The tower 2 consists of several tower sections 10 arranged on top of each other. The bottommost tower section 10 sits on a schematically represented foundation body 13, which is sunken for example fully or partially in the ground area. Alternatively, the bottommost tower section can also be connected with a foundation construction of an offshore foundation.

Fig. 2 shows a tower section 10, which is connected with the foundation 13 via an adapter 11. A self-supporting tower installation 14, which consists of several stands 16, 34, is arranged in the tower section 10. The stands 16, 34 are supported on the foot flange 26 of the tower section 10. They are arranged at distance from the tower wall and are interconnected via cross members 18. The cross members 18 are connected with the stands 16, 34 such that platforms 20, 22, 24 are formed. It is possible to walk between the platforms via a ladder (not shown). Floor plates 28 are respectively designed on the cross members of the individual platforms so that the entire platform is walkable. The floor plates 28 protrude laterally over the stands 16, 34, but are at a distance from the inside of the tower wall. The platforms serve to mount components (not shown) such as e.g. a transformer, a control unit or a converter. In addition to the ladder, the individual platforms are also interconnected by a cable guide in the vertical direction. Damping elements 44, which work between the tower installation and the inner wall of the section, are provided on the upper end of the tower installation on the stands 16. A transfer of oscillations between the tower installation and the tower wall is prevented by the damping elements 44.

Figures 3a, 3b and 3c show cross-sections along the lines A-A, B-B and C-C. The sectional representations show the platforms 20, 22, 24 arranged within the tower section 10 with the respectively associated stands 16, 34 as well as the cross members 18 and floor plates 28. In the exemplary embodiment shown, the self-supporting tower installation has twelve stands, four stands 34 of which extend up to the bottommost platform 20 and eight stands 16 of which extend up to the uppermost platform 24. Alternatively, the number of stands can be larger or smaller. The number of long and short stands can also vary depending on the loads to be received by the platforms.

Fig. 3a shows a floor plate 28, which is supported on three cross members 18. A cross member 18 progresses through the center of the tower and is fastened on two opposite-lying stands 16, while two further cross members 18 progress eccentrically and are fastened on other stands 16. The stands 16 progressing up to the top platform 24 are not distributed evenly over the periphery so that the cross members 18 do not progress parallel to each other.

Fig. 3b shows the stands 16 and the cross members 18 in the cut along the line B-B from Fig. 2. The cross members here are arranged with a different orientation with respect to the overlying platform from Fig. 3a in order to distribute the load to other stands 16.

Fig. 3c shows the cut along line C-C from Fig. 2, wherein here the floor plate 28 is only supported by two cross members 18. The middle cross member 28 can be omitted.

It can also be seen in Fig. 3c that the platform 20 is only supported by the stands 34. The stands 34 do not extend up to the further platforms 22 and 24, but rather only support the platform 20 for receiving particularly heavy loads with respect to the foot flange 26. Alternatively, the platform 20 can additionally be supported on the stands 16 in the 2-hour, 4-hour, 8-hour and 11-hour position.

In addition to the use of cross members 18, it is also possible to attach annular supports (not shown) to the stands in order to thus be able to better support the platforms in particular in their edge area. The annular supports can thereby be later designed as a closed ring, which is fastened on all stands, or as an annular segment, which is fastened on a part of the stands. Alternatively, further straight supports are attached between the supports 18, in order to reduce the support width.

The Figures 4a and 4b show as an example the fastening of a stand 16 on the foot flange 26 of the tower section 10. The stand 16 is designed as a double-T profile with two T-legs 30, 32. The T-leg 30 pointing towards the tower wall ends above the foot flange 26 so that the stand 16 is designed directly above the foot flange 26 only as a T-profile with a T-leg 32. The lower end of the profile 16 is permanently welded with a load-distribution plate 35, wherein the load-distribution plate 35 can also extend laterally above the T-leg 32. A connection flange 36 is connected with the T-leg 32 on the inwards-pointing side of the T-leg 32, which protrudes downwards over the stand 16. The connection flange 36 is screwed with the foot flange 36 via a bolt 38 on the front side in order to connect the stand 16 with the foot flange 26.

Fig. 4b shows an alternative design, in which an angled connection flange 40 is provided, which is fastened in the foot flange 26 via a bolt 42. Alternatively to the two connection flanges 36 and 40, it is also possible to connect the stand 16 with the foot flange 26 via the load-distribution plate 34.

Fig. 5 shows a further alternative design of the tower installation according to the invention. The tower section 10 has a foot flange 26. The foot flange is connected with a load-distribution plate 50 and is thus designed as a multi-part foot flange according to the understanding of the invention. The connection of the foot flange 26 and the load-distribution plate 50 takes place via connection means (not shown) in the bore hole 52. The stand 16 is designed as a double-T profile with two T-legs 30, 32. The T-leg 30 pointing towards the tower wall ends above the foot flange 26 so that the stand 16 in the area of the foot flange 26 is designed only as a T-profile with a T-leg 32. The lower end of the profile 16 is permanently welded with a load-distribution plate 35, which extends laterally over the T-leg 32. In the area of the lateral extension, the load-distribution plate 35 has bore holes, which correspond with bore holes in the load-distribution means 50. The stand 16 is connected as a foot flange with the load-distribution plate via the bore holes by means of bolt 54.

Patentkrav

1. Tårn til et vindenergianlæg, som omfatter en tårnsektion (10) med en tårnvæg (15) og en indadragende fodflange (26), hvorved der er tilvejebragt et selvbærende installation (14) til tårnsektionen (10), hvilken tårninstallation har i det mindste tre parallelle med og i afstand fra tårnvæggen (15) forløbende stolper (16, 34) og tværdragere (18), som forbinder stolperne med hinanden, **kendetegnet ved, at** stolperne (16, 34) er anbragt fordelt langs fodflangens (26) omkreds og støtter sig hver for sig på fodflangen (26).

2. Tårn ifølge krav 1, **kendetegnet ved, at** de væk fra fodflangen (26) vendende ender på stolperne (16) er frit stående og ikke forbundet med tårnvæggen (15).

3. Tårn ifølge krav 1 eller 2, **kendetegnet ved, at** tværdragerne (18) udelukkende er forbundet med stolperne (16).

4. Tårn ifølge et af kravene 1 til 3, **kendetegnet ved, at** tværdragerne (18) er anbragt vandret mellem stolperne (16, 34) med henblik på at danne mindst en platform (20, 22, 24) i tårninstallationen.

5. Tårn ifølge krav 4, **kendetegnet ved, at** en over fodflangen (26) anbragt platform (20) har korte stolper (34), som understøtter mindst en af tværdragerne i platformen (20) på fodflangen (26).

6. Tårn ifølge et af kravene 1 til 5, **kendetegnet ved, at** der er anbragt mindst et dæmpningselement (44) ved siden imellem tårninstallationen (14) og tårnvæggens inderside.

7. Tårn ifølge krav 6, **kendetegnet ved, at** dæmpningselementet (44) er fastgjort på tårninstallationen.

8. Tårn ifølge et af kravene 1 til 7, **kendetegnet ved, at** stolperne (16, 34) er tildannet som T-profiler eller som dobbelt-T-profiler.

9. Tårn ifølge et af kravene 1 til 8, **kendetegnet ved, at** stolperne (16, 34) på deres imod fodflangen (26) vendende ende har en lastfordelingsplade (35).

10. Tårn ifølge krav 9, **kendetegnet ved, at** lastfordelingspladen (35) har boringer med henblik på at blive skruet fast på fodflangen.

11. Tårn ifølge et af kravene 1 til 10, **kendetegnet ved, at** der på mindst en stolpe (16, 34) inden for området af dens fodende er tilvejebragt en forbindelsesflange (36, 40), via hvilken stolperne (16, 34) er forbundet med fodflangen.

12. Tårn ifølge et af kravene 1 til 11, **kendetegnet ved, at** fodflangen er tildannet ud i et med tårnvæggen.

13. Tårn ifølge et af kravene 1 til 11, **kendetegnet ved, at** fodflangen er forbundet med tårnsektionen via forbindelsesmidler.

14. Fremgangsmåde til rejsning af et tårn til et vindenergianlæg med følgende fremgangsmådetrin:

- tilvejebringelse af en tårnsektion (10), som på en ende har en indadragende fodflange (26),
- anbringelse af mindst tre stolper fordelt hen over fodflangens omkreds,
- fastgørelse af stolperne ved deres fodende på fodflangen på en sådan måde, at den selvbærende tårninstallation står frit understøttet inden i tårnsektionen på fodflangen,
- forbindelse af stolperne med tværdragere,
- montering af bundplader på tværdragerne til dannelse af platforme,
- montering af komponenter i tårninstallationen,

- rejsning af tårnet til vindenergianlægget med tårnsektionen, hvori allerede komponenterne er monteret i tårninstallationen.

15. Fremgangsmåde ifølge krav 14, **kendetegnet ved, at** efter monteringen af komponenterne i tårninstallationen og før tårnets rejsning prøves de monterede komponenter.

16. Fremgangsmåde ifølge krav 14 eller 15, **kendetegnet ved, at** tårnsektionen stilles opretstående til rådighed.

17. Fremgangsmåde ifølge et af kravene 14 til 16, **kendetegnet ved, at** tårnsektionen transporteres opretstående til tårnets rejsningssted.

18. Fremgangsmåde ifølge et af kravene 14 til 17, **kendetegnet ved**

- fastgørelse af en fodflange på tårnsektionen før denne stilles til rådighed.

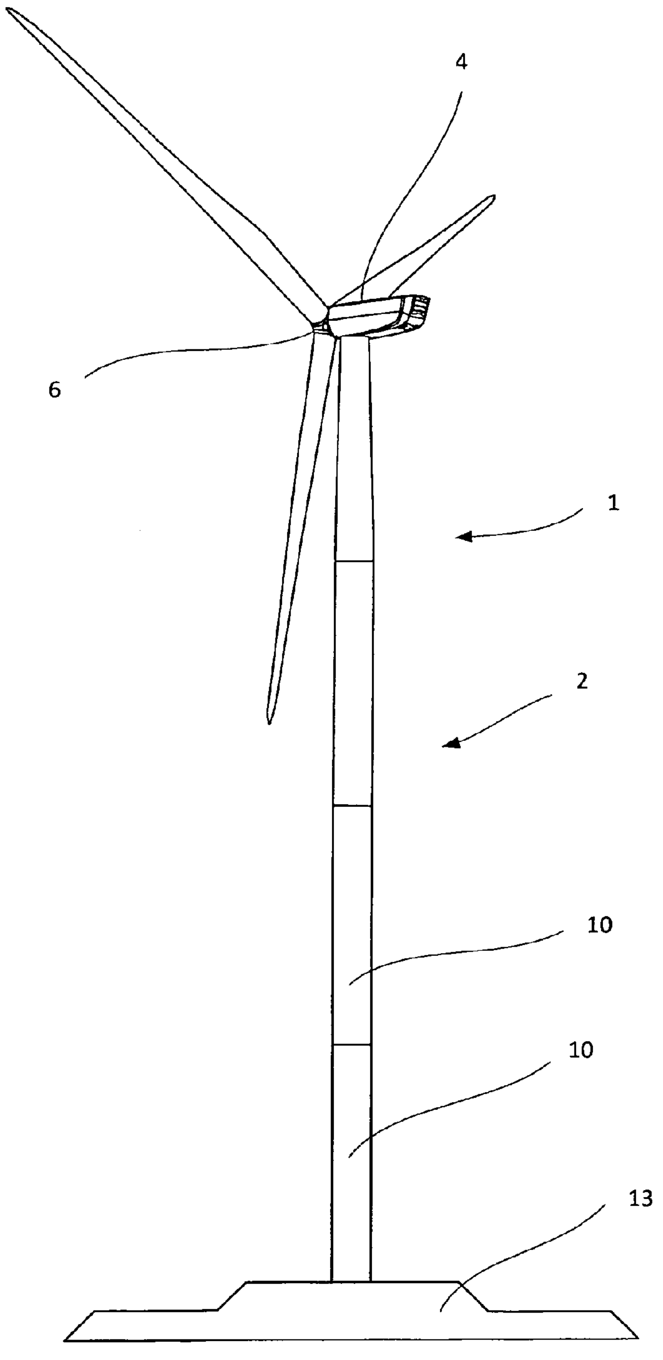

Fig. 1

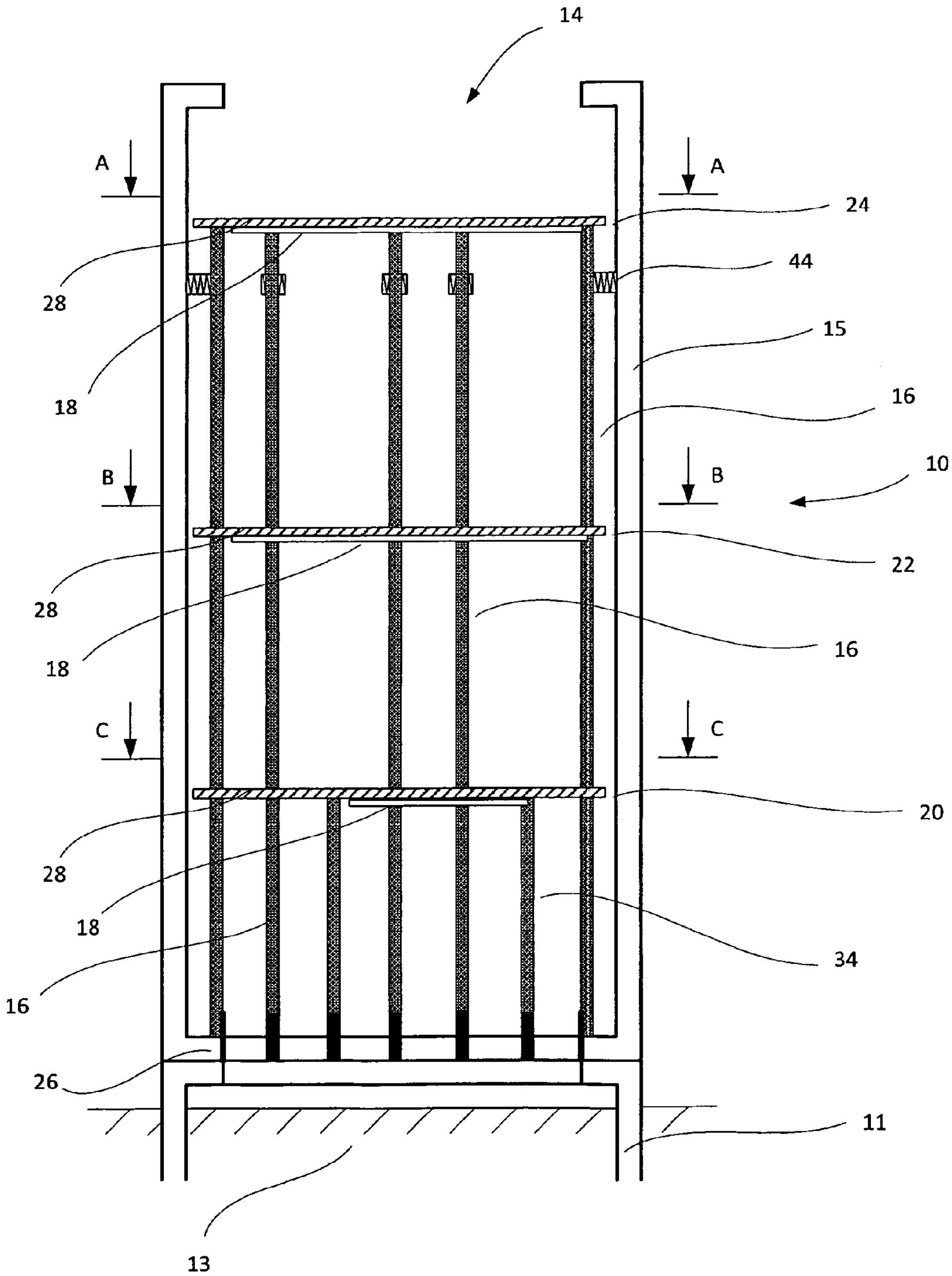

Fig. 2

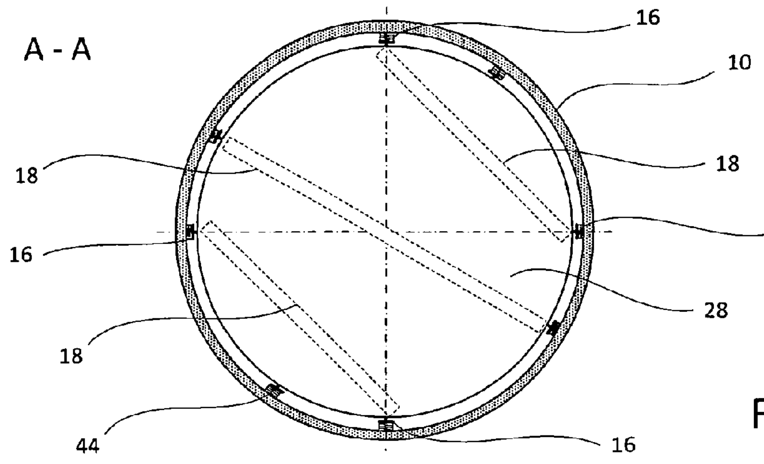

Fig. 3a

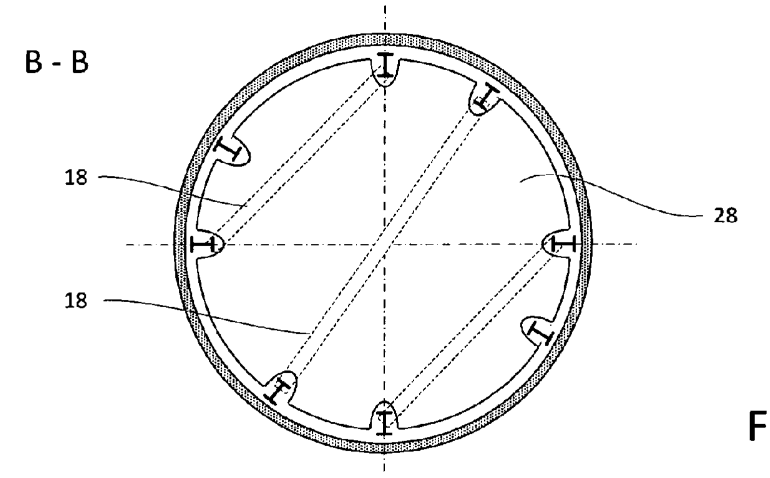

Fig. 3b

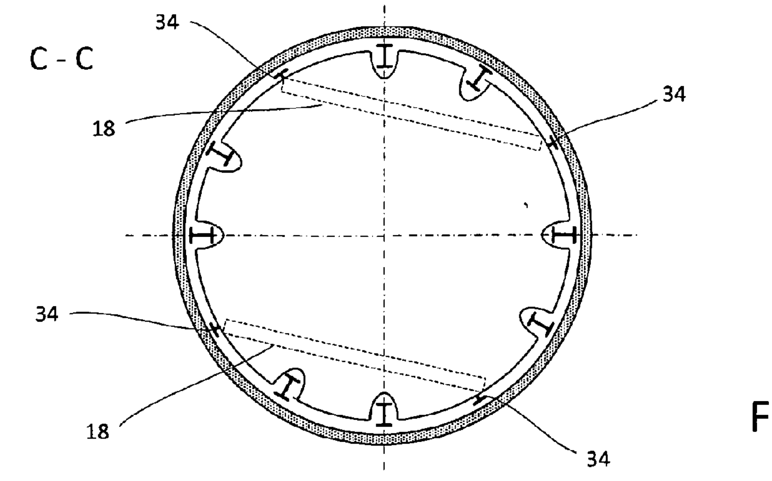

Fig. 3c

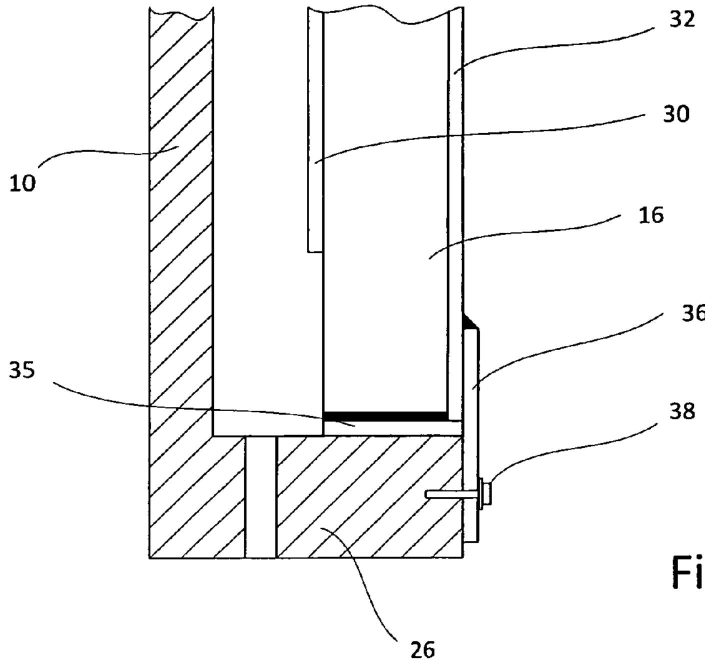

Fig. 4a

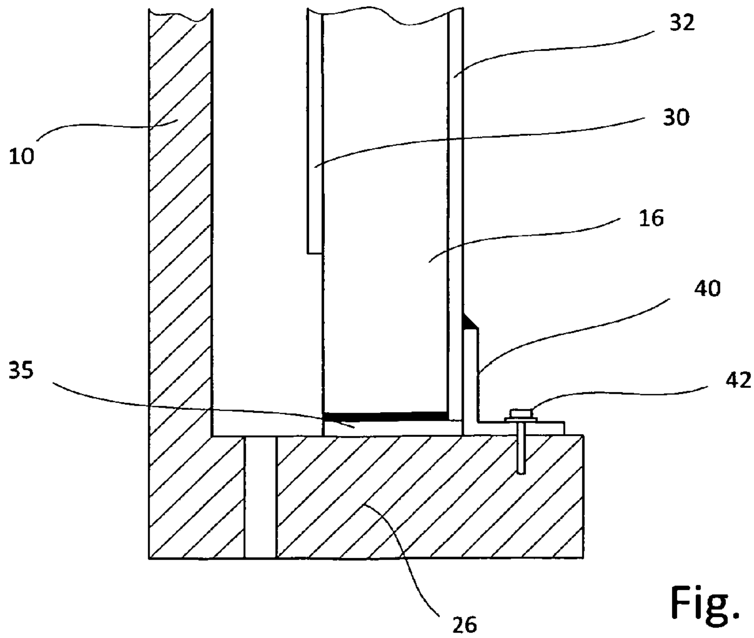

Fig. 4b

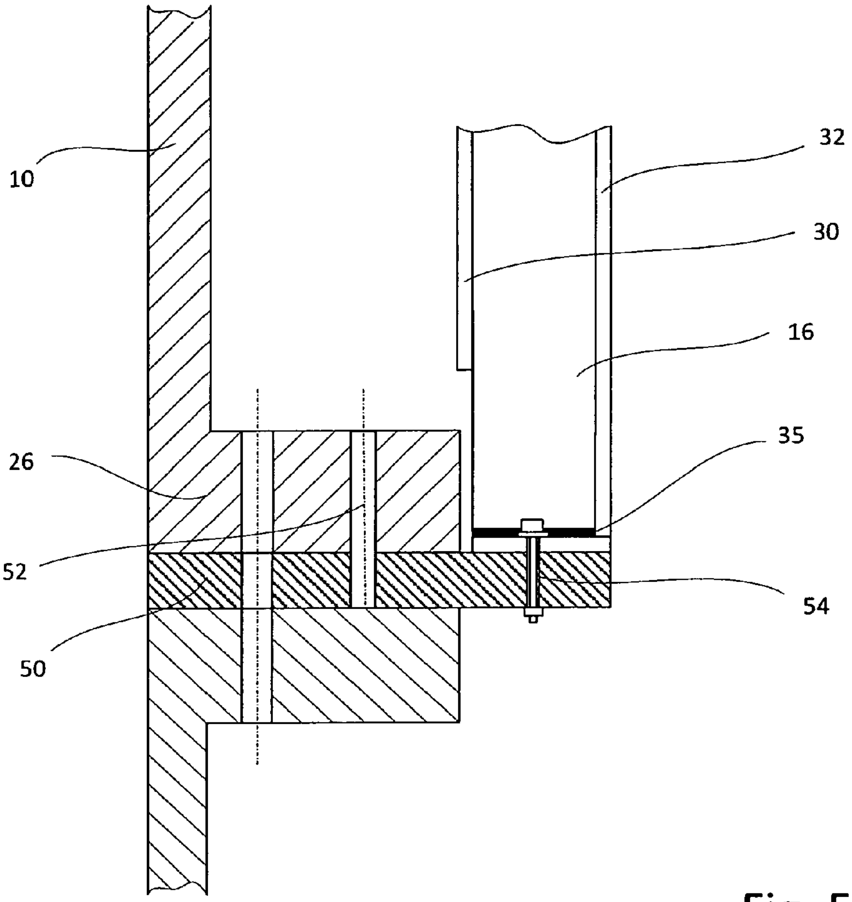

Fig. 5