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Remarks:
Amended claims in accordance with Rule 137(2) EPC.

(54) Vacuum ion pump

(57) The present invention refers to a vacuum ion pump, used for achieving high vacuum conditions, particularly suitable for applications to an environment (for instance a pipe) wherein a beam of charged particles travels. According to the invention, the ion pump (1) comprises a plurality of pumping sets (A,B,C), spaced from one another and arranged around the channel (4) of the pump (1) through which the beam of charged particles passes. Each pumping set (A,B,C) is provided with its own shield (19A,19B,19C) made of ferromagnetic material and interposed between the magnets (17B,17C) of the pumping set and the channel (4), whereby passages (23) are defined from the channel (4) to the pumping sets (A,B,C). Thanks to the structure of the ion pump according to the invention, the beam of charged particles is effectively shielded from the magnetic field of the pumping sets, without causing any relevant deterioration to the conductance and to the pumping efficiency of the ion pump (1).

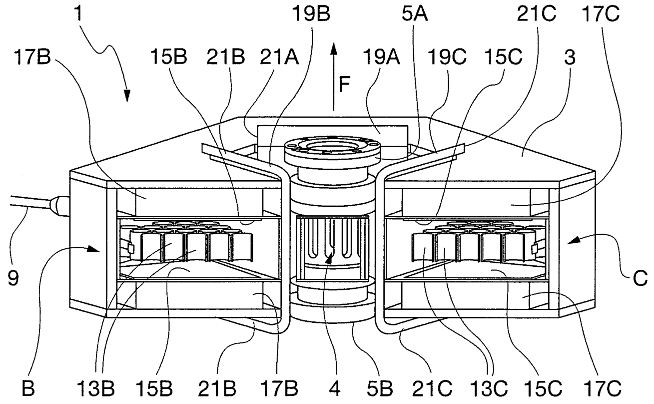

Fig. 2

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Description

Field of the invention

[0001] The present invention relates to an ion pump, used to achieve high vacuum conditions. More specifically, this invention relates to an ion pump that is particularly suitable for applications wherein the pump is used to create vacuum conditions in an environment (e.g. a pipe) inside which a beam of charged particles travels.

Prior art

[0002] There are many applications wherein a beam of charged particles travels in an environment that is maintained under high vacuum conditions.

[0003] In order to achieve the desired degree of vacuum, according to common practice vacuum ion pumps are used in such applications. In fact, ion pumps are particularly appropriate in this kind of applications because of their high reliability and the fact that they do not generate vibrations that could perturb the trajectory of the beam.

[0004] A typical example of these applications are particle accelerators. In this case, in order to maintain the accelerator as a whole at the desired pressure, a plurality of ion pumps appropriately spaced from one another are provided along the entire path of the accelerator.

[0005] As known, an ion pump includes a vacuum-tight envelope housing at least one anode formed by a plurality of hollow cylindrical pumping cells and a cathode formed by plates, for instance made of titanium, and located at opposite ends of the cells. When a potential difference is applied between anode and cathode (typically 3-9 kV), an intense electric field is generated, which results in the emission of electrons from the cathode, which electrons are then trapped in the anode cells. The electrons collide with gas molecules inside the pumping cells, causing their ionization. The positive ions thus formed, due to the effect of the electric field, are attracted by the cathode titanium plates and collide against them, giving rise to the phenomenon of "sputtering", i.e. the emission of titanium atoms from the surface of the cathode.

[0006] According to prior art, an ion pump further includes magnets placed outside the vacuum-tight envelope at opposite ends of the pumping cells for generating a magnetic field oriented parallel to the axis of the pumping cells. This magnetic field allows to impart helical trajectories to electrons, thus increasing the length of the path between the cathode and the anode and, consequently, the possibility of collisions with the gas molecules present in the pumping cells and of ionization of these molecules.

[0007] In case of applications to beams of charged particles, the magnetic field generated by the magnets of the ion pumps is a major drawback, since it perturbs the beam. More particularly, the component of the magnetic field transverse to the direction of the beam represents a significant perturbation in the trajectories of charged particles, and therefore it must be avoided.

[0008] In addition, the beam of charged particles must be protected from the titanium which is sputtered from the cathodes of the ion pumps and from the titanium debris coming from said cathodes, which may be another major perturbation for the beam itself.

[0009] In the past, in order to solve the above problem it has been devised to place the pumps far from the path of the beam of charged particles, by providing long ducts connecting said pumps to the environment that is to be kept under vacuum conditions.

[0010] This solution, however, has a very low efficiency, since the presence of long connecting ducts involves an important loss of conductance and the pumping efficiency of ion pumps results drastically reduced.

[0011] In order to overcome this problem, ion pumps have been developed that are intended to be mounted in line with the environment wherein the beam of charged particles travels. These ion pumps generally have a circular shape and they comprise a central channel through which the beam of charged particles passes.

[0012] In this type of pumps, in order to remove the perturbation associated with the magnetic field generated by the magnets of the ion pump, a cylindrical shield in ferromagnetic material is provided around the central channel of the ion pump, so as to be interposed between the magnets of the pump and the path of the charged particles.

[0013] Thanks to the high magnetic permeability of the ferromagnetic material, the magnetic field lines are closed on the shield and they do not perturb the region wherein the charged particles travel.

[0014] Pumps of this type are described for example in documents US 5,254,856, US 5,021,702, US 2002/0159891, EP 523,699.

[0015] Even this solution, however, is not free from drawbacks.

[0016] Firstly, the ferromagnetic shield provided around the channel in which vacuum conditions must be created is a major barrier to the particles of gas which must be pumped, so that the conductance and - consequently - the pumping efficiency of the ion pump are significantly reduced. The idea of providing a perforated ferromagnetic shield, as in US 2002/0159891, represents a scarcely effective compromise.

[0017] Moreover, the provision of a ferromagnetic shield inside the vacuum-tight envelope limits the choice of the material to be used, since not all the ferromagnetic materials are suitable for working under vacuum conditions. Therefore, it is necessary to make use of special steels, which result in an increase in manufacturing costs.

[0018] The main object of the present invention is to overcome the drawbacks of prior art, by providing an ion pump that is particularly suitable for applications to beams of charged particles, including means to effectively shield the beam from the magnetic field of the pump and having at the same time a high conductance, thereby allowing high pumping efficiency.

[0019] An additional object of the present invention is to provide an ion pump which includes means for effectively protecting the beam of charged particles from the sputtered titanium and from the titanium debris coming from the cathode plates.

[0020] These and other objects are achieved by an ion pump according to the invention, as claimed in the appended claims.

Disclosure of the invention

[0021] The present invention refers to an ion pump suitable to be mounted in line with the environment in which vacuum conditions must be created.

[0022] Thanks to the fact that the ion pump according to the invention includes a plurality of separate pumping sets, arranged spaced from one another around a canal and provided each with a ferromagnetic shield, the shielding structure, while maintaining its effectiveness, has a discontinuous configuration, so that the conductance is not deteriorated and the pumping efficiency is optimal.

[0023] Thanks to the fact that the ferromagnetic shields are located in slots cut in the vacuum-tight envelope, and therefore they are not under vacuum conditions, the choice of the ferromagnetic material to be used is not subject to restrictions.

[0024] Furthermore, thanks to the fact that the ferromagnetic shields are placed in said slots they can be easily replaced. More particularly, the material and the size of said shields can be modified time by time according to the needs of the final user, without intervening on the vacuum-tight envelope.

[0025] Advantageously, the presence of said slots in the ion pump according to the invention is also extremely effective to protect the channel from the titanium debris coming from the cathodes of the pumping sets.

Brief description of the Drawings

[0026] Additional features and advantages of the ion pump according to the invention will be apparent from the following description of a preferred embodiment of the invention, given by way of non-limiting example, with reference to the attached drawings, wherein:

- Figure 1 is a perspective view of an ion pump according to the invention;
- Figure 2 is a cross-section view of the ion pump of Figure 1;
- Figure 3 is a top view of the ion pump of Figure 1, with the outer casing and the magnets removed;
- Figure 4 is a side view of the ion pump of Figure 1, with the outer casing and the magnets removed;
- Figure 5 is a cross-section view of the ion pump of Figure 1, with the outer casing, the magnets and the ferromagnetic shields removed.

Description of a Preferred Embodiment of the Invention

[0027] With reference to Figure 1-5, shows an ion pump 1, which is particularly suitable to be mounted in line with an environment, such as a pipe (not shown), wherein a beam of charged particles travels.

[0028] For this purpose, the pump 1 comprises an outer casing 3 inside which a vacuum-tight envelope 11 is housed, wherein a channel 4 is provided, equipped at opposite ends of a pair of flanges 5A,5B for the connection to adjacent segments to said pipe wherein the beam travels.

[0029] Thanks to the fact that channel 4 is a direct continuance of said pipe wherein the beam travels, no step in cross section occurs.

[0030] This configuration with a pair of flanges provided at opposite ends of the channel 4 is suitable for applications in which the ion pump 1 is mounted in line with the environment to be evacuated; in other applications, only a single flange at one end of the channel for the connection with the environment to be evacuated could also be provided.

[0031] The outer casing 3 is also equipped with an exhaust port 7, which is used for connecting the pump to the pre-vacuum pump.

[0032] Power means 9 for applying the potential difference between the anode and the cathode necessary for the operation of the ion pump 1 are also connected to the outer casing 3.

[0033] As best seen in Figures 2 and 5, according to the invention, the ion pump 1 includes a plurality of pumping sets A,B,C, spaced apart from one another and arranged around the channel 4 of the pump 1.

[0034] In particular, in the illustrated embodiment three pumping sets are provided, preferably equally spaced from one another, i.e. arranged at 120° from one another with respect to channel 4. It is clear that it is also possible to provide four pumping sets arranged at 90° from one another, and so on.

[0035] Longitudinal slits 4A are provided on the lateral wall of channel 4, so that pumping is done through said slits 4A. Accordingly, the influence of the impedance budget of the vacuum system is minimized. This represents a great advantage, especially in case sensitive beams of charged particles are involved, such as in free electron lasers and other synchrotron radiation sources. Preferably, slits 4A are uniformly distributed around the lateral wall of channel 4. Thanks to this arrangement, conductance an pumping speed may be remarkably improved.

[0036] The pumping sets A,B,C are placed inside the vacuum-tight envelope 11 and each of them includes, according to known art, an anode formed by a plurality of hollow cylindrical pumping cells 13A,13B,13C, and a cathode formed by plates 15A,15B,15C, made for instance of titanium, located at opposite ends of the cells. These pumping sets also include magnets 17B,17C arranged outside the vacuum-tight envelope 11 (more specifically in the gap between the vacuum-tight envelope 11 and the outer casing 3) at opposite ends of the pumping cells 13A,13B,13C, to generate a magnetic field oriented parallel to the axis of the pumping cells.

[0037] According to the invention, in order to protect the channel 4 wherein the beam of charged particles travels from perturbations associated to the component of the magnetic field generated by these magnets transverse to the advancing direction of the beam, each pumping set A,B,C is provided with a shield 19A,19B,19C made of ferromagnetic material and interposed between said magnets 17B,17C and said channel 4.

[0038] Preferably, each of said shields 19A,19B,19C is made in the form of a substantially rectangular plate and is arranged parallel to the axis of the cylindrical cells 13A,13B,13C of the anode of the corresponding pumping set and perpendicular to the magnets 17B,17C of said pumping set. Preferably, each shield 19A,19B,19C has a width substantially equal to the width of the corresponding anode and a height slightly greater than the total height of the outer casing 3, against which it abuts thanks to folded terminal edges 21A,21B,21C provided at both opposite ends of the plate.

[0039] Concerning the thickness of the ferromagnetic shields 19A,19B,19C, it will be chosen at will within a certain range of values, depending on the particular application for which the ion pump 1 is intended, as it will become evident below.

[0040] Thanks to the presence of ferromagnetic shields 19A,19B,19C, it is possible to avoid that the channel 4 is subjected to perturbations due to the magnetic field generated by the magnets of the pumping sets A,B, C. In fact, thanks to the high magnetic permeability of the shields 19A,19B,19C, the magnetic field lines of the field generated by the magnets of each pumping set will close on the corresponding shield.

[0041] On the other hand, thanks to the fact that the ion pump 1 comprises a plurality of pumping sets A,B,C spaced from one another and that each pumping set is provided with its own ferromagnetic shield 19A,19B,19C, the shielding structure, intended as the totality of ferromagnetic shields interposed between the pumping sets and the channel 4, turns out to have a discontinuous configuration, very different from the cylindrical shields of prior art. Indeed, passages 23 for gas to be pumped are defined between the ferromagnetic shields 19A,19B, 19C; thanks to the presence of said passages 23 connecting the channel 4 to the regions of the vacuum-tight envelope 11 wherein the pumping sets A,B,C are placed, the conductance is not deteriorated and the pumping efficiency of the pump 1 can be kept high.

[0042] Advantageously, according to the invention, the ferromagnetic shields 19A,19B,19C are not subjected to vacuum conditions, which would restrict the choice of the material to be used.

[0043] Conversely, for each ferromagnetic shield a corresponding slot 25A,25B,25C having a substantially rectangular cross section is cut in the vacuum-tight envelope 11, the shield being inserted in the corresponding slot. Consequently, whatever the degree of vacuum created by the ion pump 1 is, the ferromagnetic shields 19A, 19B,19C are at atmospheric pressure conditions. Therefore, the material with the most favourable magnetic characteristics (e.g. depending on the specific application) can be selected for manufacturing said shields, without any other kind of constraint.

[0044] Also the thickness of the ferromagnetic shields 19A,19B,19C can be chosen according to the specific needs of the final user. In fact, it is clear, for instance from Figure 3, that plates of different thicknesses can be inserted in the slots 25A, 25B, 25C, provided that the plates thickness is lower than the thickness of the slot themselves. Consequently, choosing the thickness of said slots high enough, it is possible to choose in a wide range of ferromagnetic shields of different thicknesses. Obviously, an upper threshold to the thickness of said slots is imposed by the need of maintaining the conductance inside the vacuum-tight envelope 11 high.

[0045] From the above disclosure, it is clear that the ion pump according to the invention allows to achieve the main object set forth above, as it allows to obtain an ion pump with high conductance and high efficiency in terms of pumping, which can be effectively used in applications with beams of charged particles, thanks to an effective shielding of the magnetic field generated by the magnets 17B,17C of the pumping sets.

[0046] Moreover, it is to be noted that the particular arrangement of the magnetic shields 19A,19B,19C and of the slots 25A,25B,25C containing said shields also provides an excellent shielding of the channel from the titanium coming from the cathode plates 15A,15B,15C of the pumping sets.

[0047] In fact, thanks to the presence of the slots 25A, 25B,25C there is no free optical path from said cathodes to said channel, i.e. the titanium produced at the cathodes 15A,15B,15C does not "see" the channel 4.

[0048] Consequently, the ion pump according to the invention also allows to achieve the additional object set forth above.

[0049] It is clear that the embodiment here illustrated in detail has been given by way of non-limiting example and that many modifications and variations are possible without departing from the scope of the invention, as defined by the appended claims.

Claims

1. Vacuum ion pump (1), comprising an outer casing (3) housing a vacuum-tight envelope (11) comprising a channel (4) provided at least at one end with a flange (5A,5B) for connection to the environment to be evacuated, said pump comprising a plurality of pumping sets (A,B,C), spaced from one another and arranged around said channel (4), each pumping set (A,B,C) comprising an anode formed by a plurality

of hollow cylindrical pumping cells (13A,13B,13C) and a cathode formed by plates (15A,15B,15C) housed inside said vacuum-tight envelope (11) and further comprising magnets (17A,17B) placed outside said vacuum-tight envelope (11) at opposed ends of said pumping cells (13A,13B,13C) for generating a magnetic field parallel to the axis of said pumping cells, **characterised in that** each pumping set (A,B,C) is provided with a shield (19A,19B,19C) made of ferromagnetic material and interposed between said magnets (17B,17C) of said pumping set and said channel (4), passages (23) connecting said channel (4) to said pumping sets (A,B,C) being defined between said ferromagnetic shields (19A,19B, 19C).

2. Vacuum ion pump (1) according to claim 1, wherein said ferromagnetic shields are at atmospheric pressure conditions.

3. Vacuum ion pump (1) according to claim 2, wherein for each of said ferromagnetic shields (19A,19B, 19C) a slot (25A,25B,25C) is cut in the vacuum-tight envelope (11), inside which slot a corresponding shield is inserted.

4. Vacuum ion pump (1) according to any of the preceding claims, wherein each of said shields (19A, 19B,19C) is shaped as a substantially rectangular plate and it is arranged parallel to the axis of the cylindrical cells (13A,13B,13C) of the anode of the corresponding pumping set (A,B,C) and perpendicular to the magnets (17B,17C) of said pumping set (A,B,C).

5. Vacuum ion pump (1) according to claim 4, wherein each of said ferromagnetic shield (19A,19B,19C) has a width substantially equal to the overall width of the anode of the corresponding pumping set (A, B,C) and a height slightly greater than the overall height of said outer casing (3).

6. Vacuum ion pump (1) according to claim 5, wherein each of said ferromagnetic shields (19A,19B,19C) has folded terminal edges (21A,21B,21C) provided at both opposed ends thereof for abutting against the walls of said outer casing (3).

7. Vacuum ion pump (1) according to claim 3, wherein each of said slots (25A,25B,25C) blocks any optical path between the corresponding pumping set (A,B, C) and said channel (4).

8. Vacuum ion pump (1) according to any of the preceding claims, wherein said pumping sets (A,B,C) are arranged equally spaced from one another around said channel (4).

9. Vacuum ion pump (1) according to claim 8, wherein three pumping sets are provided, arranged at 120° from one another around said channel (4).

10. Vacuum ion pump (1) according to claim 8, wherein four pumping sets are provided, arranged at 90° from one another around said channel (4).

11. Vacuum ion pump (1) according to any of the preceding claims, longitudinal slits (4A) are provided in the lateral wall of said channel (4).

12. Vacuum ion pump (1) according to claim 11, wherein said slits (4A) are uniformly distributed around said lateral wall of said channel (4).

Amended claims in accordance with Rule 137(2) EPC.

1. Vacuum ion pump (1), comprising an outer casing (3) housing a vacuum-tight envelope (11) comprising a channel (4) provided at least at one end with a flange (5A,5B) for connection to the environment to be evacuated, said pump comprising a plurality of pumping sets (A,B,C), arranged around said channel (4), each pumping set (A,B,C) comprising an anode formed by a plurality of hollow cylindrical pumping cells (13A,13B,13C) and a cathode formed by plates (15A,15B,15C) housed inside said vacuum-tight envelope (11) and further comprising magnets (17A, 17B) placed outside said vacuum-tight envelope (11) at opposed ends of said pumping cells (13A,13B, 13C) for generating a magnetic field parallel to the axis of said pumping cells, said pumping sets (A,B, C) are provided with a ferromagnetic shield (19A, 19B,19C) interposed between said magnets (17B, 17C) of said pumping set and said channel (4),
characterised in that said pumping sets (A,B,C) are spaced from one another, wherein each pumping set (A,B,C) is provided with its own ferromagnetic shield (19A,19B,19C), and passages (23) connecting said channel (4) to said pumping sets (A,B,C) being defined between said ferromagnetic shields (19A,19B,19C).

2. Vacuum ion pump (1) according to claim 1, wherein said ferromagnetic shields are at atmospheric pressure conditions.

3. Vacuum ion pump (1) according to claim 2, wherein for each of said ferromagnetic shields (19A,19B, 19C) a slot (25A,25B,25C) is cut in the vacuum-tight envelope (11), inside which slot a corresponding shield is inserted.

4. Vacuum ion pump (1) according to any of the preceding claims, wherein each of said shields (19A, 19B,19C) is shaped as a substantially rectangular plate and it is arranged parallel to the axis of the cylindrical cells (13A,13B,13C) of the anode of the corresponding pumping set (A,B,C) and perpendicular to the magnets (17B,17C) of said pumping set (A,B,C).

5. Vacuum ion pump (1) according to claim 4, wherein each of said ferromagnetic shield (19A,19B,19C) has a width substantially equal to the overall width of the anode of the corresponding pumping set (A, B,C) and a height slightly greater than the overall height of said outer casing (3).

6. Vacuum ion pump (1) according to claim 5, wherein each of said ferromagnetic shields (19A,19B,19C) has folded terminal edges (21A,21B,21C) provided at both opposed ends thereof for abutting against the walls of said outer casing (3).

7. Vacuum ion pump (1) according to claim 3, wherein each of said slots (25A,25B,25C) blocks any optical path between the corresponding pumping set (A,B,C) and said channel (4).

8. Vacuum ion pump (1) according to any of the preceding claims, wherein said pumping sets (A,B,C) are arranged equally spaced from one another around said channel (4).

9. Vacuum ion pump (1) according to claim 8, wherein three pumping sets are provided, arranged at 120° from one another around said channel (4).

10. Vacuum ion pump (1) according to claim 8, wherein four pumping sets are provided, arranged at 90° from one another around said channel (4).

11. Vacuum ion pump (1) according to any of the preceding claims, longitudinal slits (4A) are provided in the lateral wall of said channel (4).

12. Vacuum ion pump (1) according to claim 11, wherein said slits (4A) are uniformly distributed around said lateral wall of said channel (4).

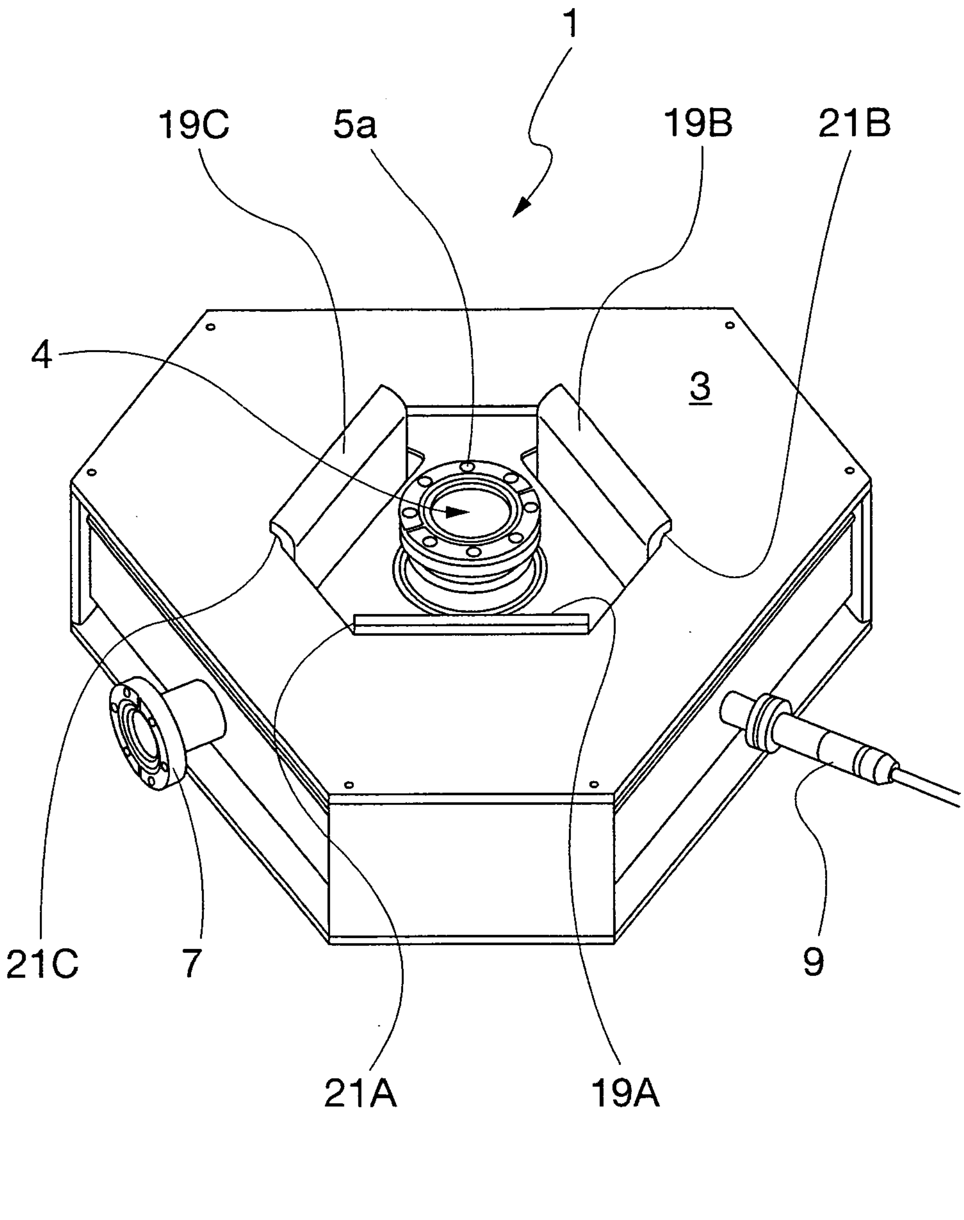

Fig. 1

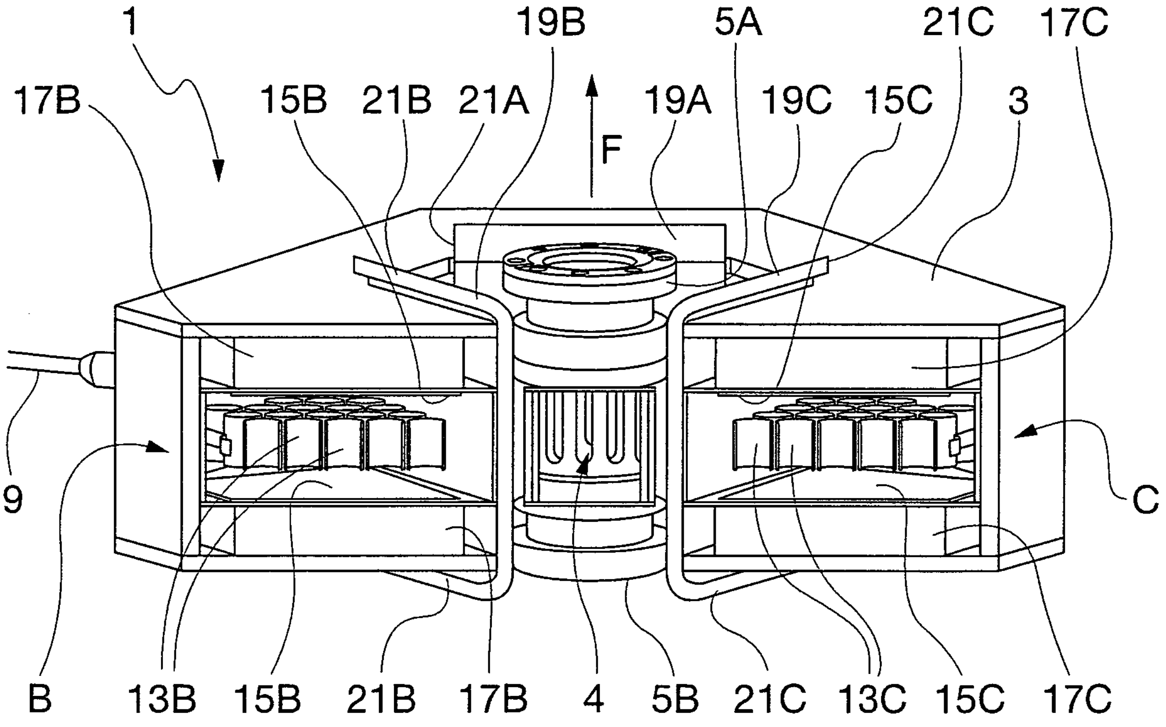
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Fig. 2

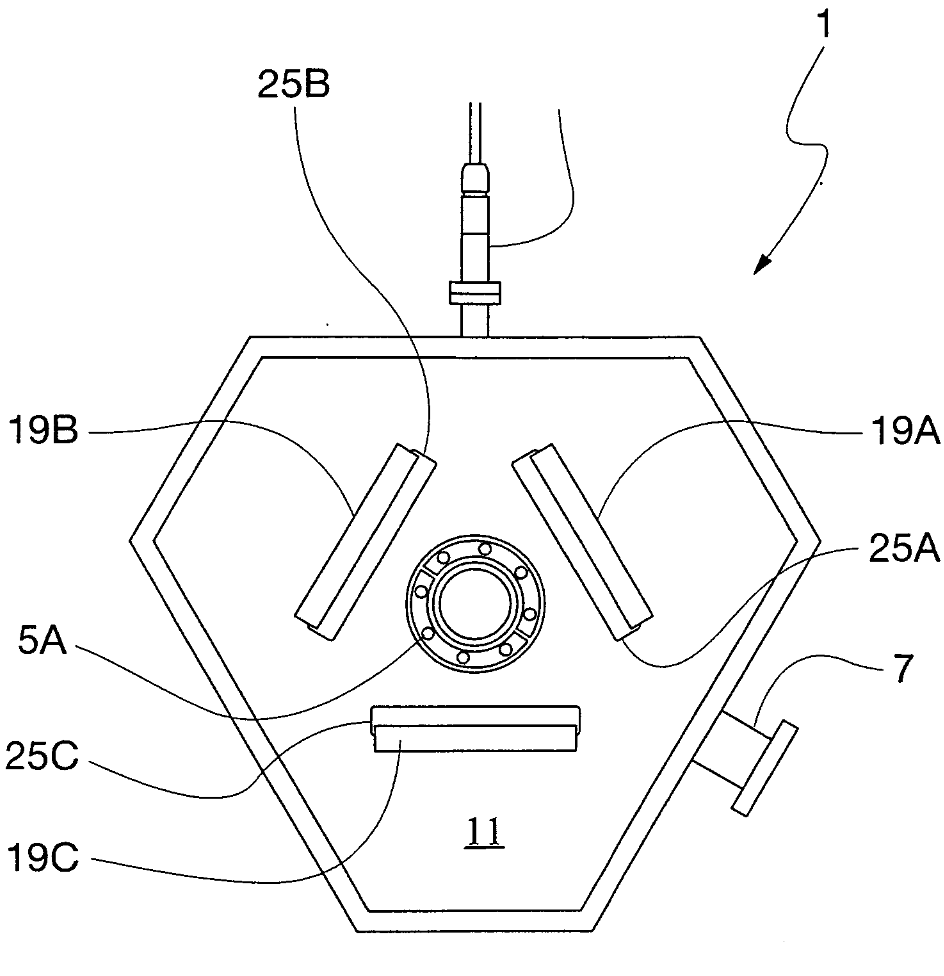

Fig. 3

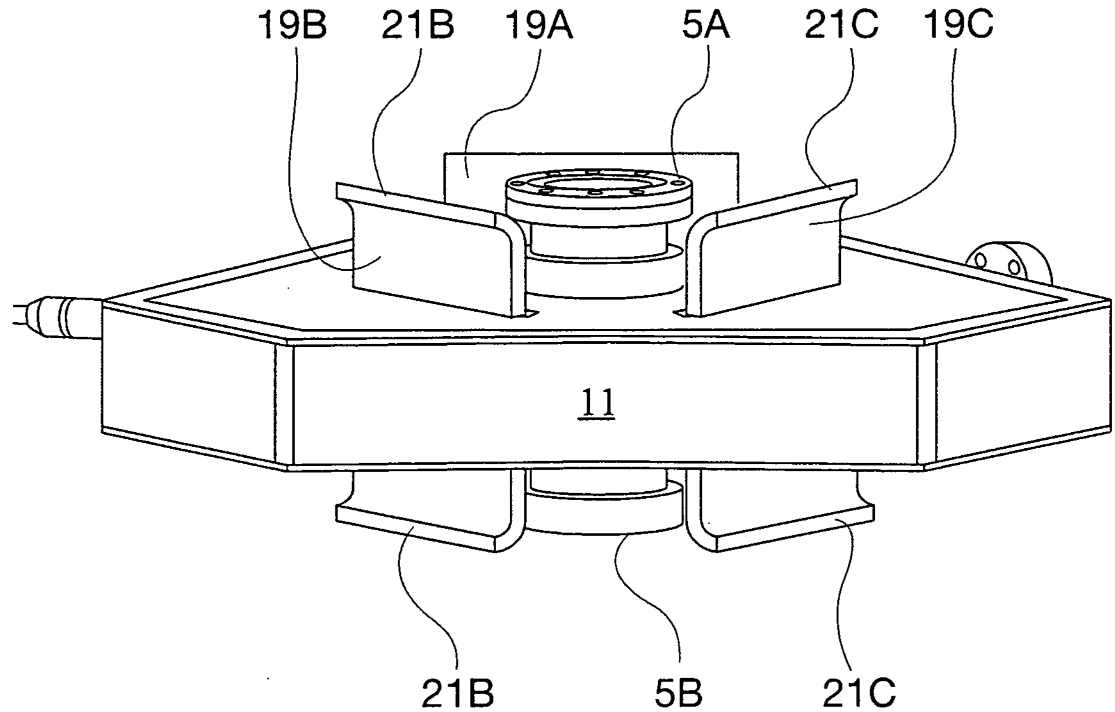

Fig. 4

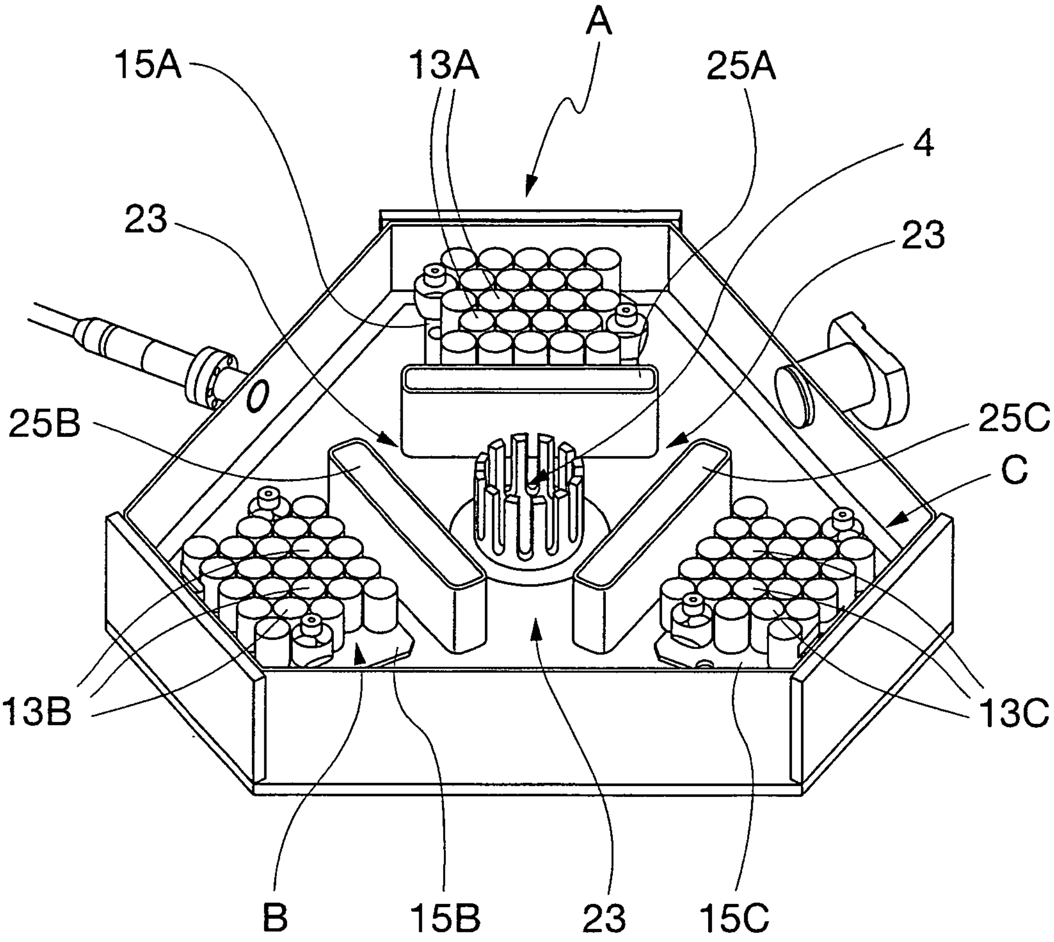

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 10 00 9838

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	US 3 117 247 A (JEPSEN ROBERT L) 7 January 1964 (1964-01-07) * figure 2 * -----	1	
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TECHNICAL FIELDS SEARCHED (IPC)
H01J

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	24 February 2011	Peters, Volker

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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