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(54) Improved wet electrostatic precipitator

(57) Wet electrostatic precipitator for purifying a gas, comprising a plurality of vertically arranged tubular collector electrodes (2) made of a substantially porous membrane and a plurality of discharge electrodes (3) each being arranged along each of said vertical axis of said tubular collector electrodes (2).

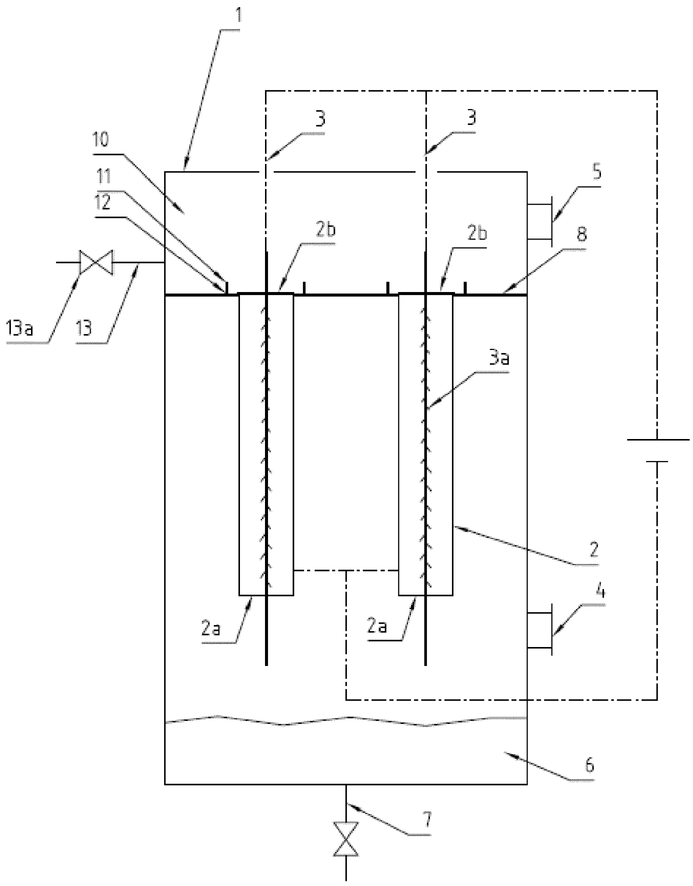

Fig.1

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Description

Field of the invention

[0001] The present invention relates to an electrostatic precipitator (ESP) for precipitating particles in exhaust gases. Especially, it relates to a wet electrostatic precipitator (WESP) which also allows for absorption of gaseous impurities in exhaust gases.

Background

[0002] According to the definition by IUPAC, an electrostatic precipitator is a device *"... which separates particles from a gas stream by passing the carrier gas between pairs of electrodes across which a unidirectional, high-voltage potential is placed The particles are charged before passing through the field and migrate to an oppositely charged electrode."*

[0003] Electrostatic precipitators (ESP:s) are efficient collectors of small particles present in gases. They are for example used to remove particles from power plant exhaust gases. In a typical conventional ESP, vertical wire electrodes are placed in the midsection of a channel formed between vertical parallel planar collector substrates. The heavy, typically steel, plates are suspended from a support structure that is anchored to an external framework. The gas flows horizontally through the ESP. As a DC voltage is applied between the wire electrodes, i.e. discharging electrodes, and the grounded collector electrodes, a corona discharge is induced between them. The corona discharge may cause particles in the gas to become charged and thereby force the electric field to migrate toward, and be collected on, the collector electrodes. Thus, a dust layer is formed on the collector electrodes. The dust layer may periodically be removed from the collector electrodes by hammers imparting sharp blows to the edges of the plates, typically referred to as *"rapping"* the plates. When ESP:s are rapped, the dust layer is supposed to drop vertically downward from the plates due to a shear force between the plate and the parallel dust layer.

[0004] Rather than using dry collector electrodes, wetted electrodes, i.e. electrodes having falling liquid film at its surface may be used. As an example, US 1,968,334 discloses an ESP with vertical wetted tubular collector electrodes. The invention disclosed in US 1,968,334 is concerned with the problem of achieving a uniform thin liquid film at the inner surface of the solid tubular collector electrode. As the distance between the discharge and collector electrode preferably should be the same over the entire inner surface of the collector electrode it is important to have a liquid film of uniform thickness. Further, dry spots, i.e. non-wetted areas, are very disadvantageous as the surface will corrode and precipitated particles may stick to the surface and not be washed away subsequently. Thus, any dry spots may eventually result in holes in the collector electrode or build ups at the collector electrode. In addition the outer surface of a tubular collector electrode will be exposed to the incoming gas flow. For gases comprising corrosive impurities, such as HCL, there is a great risk for corrosion at the outer surface.

[0005] The problem of particles sticking to the surface of tubular collector electrodes is addressed in US 1,393,712. The ESP disclosed therein has heated tubular collector electrodes in order to keep precipitated tarry particles in fluid state.

[0006] Attempts to replace the heavy steel plates that typically are used for ESP:s within the art have been made. In US 6,231,643 an electrostatic precipitator having a planar collector electrode comprising a membrane of intertwined fibers, and having wetting properties and a tubular discharge electrode is disclosed. Further, the collector electrode is mounted to a variable tensile loader. The tensile loader serves to keep the membrane taut, but may also serve for rapping of the membrane if operated dry. In operating the precipitator wet, water is applied to and adsorbed in the electrode. The applied water flows through the electrode and is subsequently being collected. Although the membrane may be kept taut, the distance between the planar collector electrodes and the tubular discharge electrode will vary over the collector electrode. Thus, efficient precipitation will only be achieved over very limited part of the collector electrode. In addition, the fluid flow is perpendicular to the axis of the tubular discharge electrode.

[0007] In US 6,783,575 a laminar flow (Re<2300), wet electrostatic precipitator is disclosed. The laminar flow is stated to be achieved as the collector electrode, similar to the one in US 6,231,643 being made of a substantially water-saturated porous membrane having a water-wetted, exterior surface, as well as the discharge electrode, are substantial planar and disposed in the gas stream substantially parallel to the direction of flow of the gas stream. Further, it is stated that laminar flow is of importance, as turbulent flow will prevent substantial collection of acid aerosols and fine particles.

[0008] In addition, also JP 6319937 discloses use of tubular collector electrodes for a WESP. The collector electrode comprises a pair of vertical wire gauzes installed on the lower side of an oblong rectangular shaped metal plate on which processing fluid is emitted. In contrast to the invention disclosed in US 6,783,575, but similar to the invention disclosed in US 6,231,643, the distance between the tubular collecting electrodes and the cylindrical emitter electrode will vary over the collector electrode. Thus, efficient precipitation will only be achieved over very limited part of the collector electrode.

[0009] Thus, there is a need in the art for an ESP overcoming the above mentioned disadvantages.

Summary

[0010] Consequently, the present invention seeks to mitigate, alleviate, eliminate or circumvent one or more of the above-identified deficiencies in the art and disadvantages singly or in any combination by providing a wet electrostatic precipitator, having at least one tubular collector electrode, but preferably several tubular collector electrodes, made of a substantially porous membrane. The wet electrostatic precipitator comprises a housing, having an inlet for said gas to be purified, a gas outlet for discharging the purified gas. The housing encloses at least one, such as plurality of vertically arranged tubular collector electrodes, having open lower and upper ends, and at least one, such as a plurality of discharge electrodes, each being arranged along the vertical axis of each of said tubular collector electrodes. Further, the wet electrostatic precipitator has means for wetting the tubular collector electrodes at their upper ends. In the housing, a horizontally arranged header plate demarcates a space at the upper end of the housing. The upper ends of the tubular collector electrodes extend above the header plate through openings in the header plate into the spacing demarcated by the header plate. Alternatively, the upper ends of the tubular collector electrodes end at openings in the header plate. The gas outlet is arranged in communication with the spacing demarcated by the header plate, while the inlet is arranged below the header plate. Alternatively, the inlet is arranged in communication with the spacing demarcated by the header plate, while the gas outlet being arranged below the header plate.

[0011] A further aspect of the invention relates to method of purifying a gas. In such a method, the gas is introduced into such a wet electrostatic precipitator as just described herein above via the inlet and the purified gas is obtained via the outlet. In purifying the gas, the tubular collector electrode is being continuously wetted at its upper end and an electrical field is applied between the discharge and collector electrode. Further, the temperature of gas to be purified is above the dew point of the gas when introduced into the wet electrostatic precipitator. Furthermore, the temperature of the purified gas is above the dew point of the gas when leaving the wet electrostatic precipitator.

[0012] Further advantageous features of the invention are defined in the dependent claims. In addition, advantageous features of the invention are elaborated in embodiments disclosed herein.

Brief description of the drawings

[0013]

Fig. 1 Depicts a cross-section of WESP.

Fig. 2 Depicts a tubular collector electrode (2), having mounting means (2c), and extending through an opening in a header plate (8), wherein a collar (11) have been arranged around the opening in the header plate (8), said collar (11) being provided with vertical slots (22) extending from the upper edges of the collar (11).

Fig. 3 Depicts a tubular collector electrode (2), having mounting means (2c), and extending through an opening in a header plate (8), wherein a collar (11) have been arranged around the opening in the header plate (8), said collar (11) being provided with openings (12) arranged at the lower end of the collar at the attachment of the collar 8 to the header plate 8.

Embodiments

[0014] An embodiment relates to a wet electrostatic precipitator comprising a housing 1 enclosing at least one, but typically a plurality of vertically arranged tubular collector electrodes 2 and at least one, but typically a plurality of discharge electrodes 3 arranged along the vertical axis of the tubular collector electrodes 2. In order to receive a gas to be purified, such as flue gas or a process gas, from aerosols or solid matter, the housing has a gas inlet 4. The gas inlet may be arranged at the lower end of the housing 1. Within in the housing, the wet electrostatic precipitator is arranged to allow for a gas to be purified, i.e. a gas comprising particles and/or gaseous impurities, to be lead through the tubular collector electrodes 2. Preferably, the gas to be purified may enter the vertically arranged tubular collector electrodes at their lower open ends 2a and exit through the upper open ends 2b. Further, the housing has a gas an outlet 5 for discharging the purified gas. The outlet 5 may typically be arranged at the upper end of the housing 1.

[0015] The tubular collector electrodes 2 are typically essentially vertically arranged. Further, they do typically have an essentially circular axial cross section. A discharge electrode 3 is arranged along the vertical axis of each collector electrodes 2. The discharge electrode 3 may typically be a wire, a tube or a rigid rod. Further, the discharge electrode 3 may typically have spikes or tabs 3a extending from the discharge electrode 3 and ending in sharp tips. By arranging a discharge electrode 3 along the vertical axis of each tubular collector electrodes 2, a uniform distance between the collector electrode 3 and the discharge electrode 2 may be accomplished over the entire surface of the collector electrode. Thus, efficient electrostatic precipitation may be achieved. Furthermore, arranging a discharge electrode 3 along the vertical axis of each tubular collector electrodes 2 will imply that the strength of the electrical field not will be uniform. As a consequence, high precipitation efficiency will be achieved. Compared to ESP:s operating with planar emitter electrodes, such as disclosed by US 6,783,575, extended discharge electrodes arranged along the vertical axis of a tubular collector electrode will provide a higher current before spark over occurs, implying that higher electrostatic precipitation efficiency may be achieved. Said advantage is even more pronounced if the discharge electrodes 3 have tabs or spikes 3a extending from the discharge electrode 3 and ending in sharp tips.

[0016] As is well known to the skilled person, the discharge electrodes 3 may be connected to a DC source, while the collector electrodes 2 typically are grounded. By applying an electrical field between the discharge 3 and collector 2 electrodes, corona discharges may cause particles, present within the gas to be purified, to become charged and whereby forced by the electric field to migrate toward, and be collect on, the collector electrodes 2. Contrary to arrangements within the art, wherein a plurality of planar collector electrodes are arranged parallel with respect to each other and interposed by discharge electrodes, the voltage applied over each tubular collector electrode of a plurality of tubular collector electrodes may be separately adjusted. Thus, the possible variation in diameter of different tubular collector electrode may be compensated for and very similar electrical field may be applied in each electrode pair.

[0017] The gas to be purified may enter the vertical tubular collector electrode 2, at its lower open end 2a, flow upwards through the vertical tubular collector electrode 2, and exit the tubular collector electrode 2 via its upper open end 2b. Herein such a flow is denoted counter flow. Similarly, the gas to be purified may alternatively enter the vertical tubular collector electrode 2, at its upper end 2b, flow through downwards through the vertical tubular collector electrode 2, and exit the tubular collector electrode 2 via its lower open end 2a.

[0018] Typically the diameter of each collector electrode 2 may be 100 to 1,000 mm. The length of each the collector electrode 2 may be from just a few decimeters (e.g. 0.1 meter) up to 10 meters.

[0019] The collector electrodes 2 are made of a substantially porous membrane. By continuously wetting parts of the porous collector electrode membrane at the upper end of the tubular collector electrode 2b, the collector electrode 2 will, due to capillary action and gravimetrical transport, become water-saturated. Thus, the collector electrode 2 will have a water-wetted, interior surface. Furthermore, once the porous collector electrode membrane has been become water-saturated, a falling film may be established at the inner surface of the tubular collector electrode. As an electrical field may be applied between the discharge electrode 3 and the collector electrode 2, the falling water film, at the water-wetted, interior surface of the collector electrode 2, may act as conductor and trap particle matter being brought into contact with the water. Further, gaseous impurities present in the gas, such as HC1 and HF, to be purified may be passively absorbed in the falling water film at the water-wetted, interior surface. As the water film typically will have significantly lower temperature than the gas to be purified, the gas may be cooled during its passage through the tubular collector electrodes. Eventually, gaseous impurities, such as Hg(0) and dioxines, may thus be condensed and subsequently precipitated at the water-wetted, interior surface of the tubular collector electrodes. Typically, the water applied to the upper end of the tubular collector electrode 2b will have a temperature of less than about 30°C, such as 10 to 30°C. Further, the temperature of the water applied to the upper end of the tubular collector electrode 2b may be above 10°C. As the dewpoint of the gas to be purified typically is about 50 to 75°C, condensation of impurities may eventually be achieved if the temperature of the water applied to the upper end of the tubular collector electrode 2b is below 50°C.

[0020] According to an embodiment, the wet electrostatic precipitator is operated in manner such that the temperature of the gas to be purified as well as the temperature of the purified gas is above the dew point of the gas. By operating the wet electrostatic precipitator in such a manner, the corrosive stress of materials within the wet electrostatic precipitator may be lowered, or even eliminated. Thereby the need to use corrosion resistant material for constructing the WESP may be limited to certain parts of the WESP as the bottom hopper and the drainage.

[0021] An embodiment relates to a method of purifying a gas. In such a method, the gas to be purified is introduced into such a wet electrostatic precipitator as described herein via the inlet 4 and the purified gas is obtained via the outlet 5. In purifying the gas, the tubular collector electrodes 2 is being continuously wetted at its upper end 2b and an electrical field is applied between the discharge electrode 3 and collector electrode 2. Further, the temperature of the gas to be purified is above its dew point when introduced into the wet electrostatic precipitator. Furthermore, the temperature of the purified gas is above the dew point of the gas when leaving the wet electrostatic precipitator. In such a method, the temperature of the water applied to the upper ends 2b of said tubular collector electrodes 2 may be below the dew point of the gas to be purified. As an example, the temperature of the water applied to the upper ends 2b of said tubular collector electrodes 2 is 10 to 30°C.

[0022] Typically, conventional WESP:s are combined with a scrubbing step, preceding the electrostatic precipitation. Thereby gaseous impurities, such as HC1, SO_2, SO_3, and HF, may be removed. According to the present embodiment, the gas to be purified has a temperature well above its dew-point. If no scrubbing steps precedes the electrostatic precipitation this is typically the case. By operating the wet electrostatic precipitator in a manner wherein the temperature water applied to the upper end of the tubular collector electrodes 2b is significantly lower than the temperature of the gas to be purified, condensation of impurities of certain species, such Hg(0), dioxins etc. may occur at the interface of the falling film of water and the gas to be purified, without cooling the gas to below its dew-point. Further, gaseous impurities, such as HC1, SO_2, SO_3, and HF, may be absorbed in the falling film of water and thereby removed from the gas to be purified.

[0023] As the collector electrode 2 is a continuously wetted, substantially porous membrane, its inner surface will be cleaned and precipitated and absorbed impurities will be removed continuously. Thereby, no ash layer giving an insulating effect is formed at the inner surface of the collector electrode. As a consequence, no electric field strength suppression is seen. Furthermore, compared to a solid tube with a falling water film at its inner surface, the described collecting electrodes will allow for a flow of a larger water volume at a given cross section, whereby an increased cooling effect may achieved and as result a more efficient condensation of gaseous impurities.

[0024] Further, the use of the described collecting electrodes 2 minimizes the formation of back corona, as the collector electrodes 2 are constantly wetted and cleaned by water uniformly distributed via capillary transport and being an excellent conductor. Therefore, the electrostatic precipitator may deliver far greater energizing power due to higher voltages and field strengths, and can effectively charge even submicron particles. Thereby, the potential of the membrane-based electrostatic precipitator in controlling acid aerosols, condense hydrocarbons and soot, and fine and ultra-fine particles is very good.

[0025] Use of water as collector electrode may further eliminate the re-entrainment often seen in dry operating precipitators as the collected particle will "stick to" or be absorbed in the water and carried away.

[0026] As also the outer surface of each of the porous collecting electrodes will be continuously wetted, said surface may act to absorb impurities in the incoming gas to be purified before being introduced into the tubular collecting electrodes. According to one embodiment, the gas inlet 4 is arranged between the lower ends 2a and the upper ends 2b of the tubular collector electrodes. Thereby, the gas to be purified may flow along the outer wetted surface of the tubular collecting electrodes before entering into the lower ends 2a or the upper ends 2b of the tubular collecting electrodes.

[0027] According to an embodiment, the term "*porous membrane*" as used herein, is intended to mean that the material referred to has pores or passages through the structure that permit water to flow through the structure. The porous membrane may be made of a woven or non-woven fiber, a combination of particulate and binder, a sponge or some other configuration that is porous.

[0028] In a preferred embodiment, the porous membrane is a woven fiber material that has small pores and passages between the fibers through which water can flow in various directions. The porous membrane may be arranged such that the water flows along the fibers' longitudinal axes.

[0029] According to an embodiment, the porous membrane comprises fibrous or woven membrane material, such as carbon or silica fibers, or a stainless steel mesh. The wetted porous membrane, acting as collector electrode, does not have to be made of conductive material, as the water will act as the conductor. Preferably, the porous membrane is made of an essentially none-corrosive material as the corrosive breakdown often seen with solid tubular collector electrodes then may be avoided.

[0030] According to a preferred embodiment, the porous membrane is a woven silica fiber membrane. As an example, such woven silica fiber membrane is sold under the trademark OMNISIL. Use of porous membranes made of non-corrosive materials, such as silica fiber membrane, are suitable for implementation in purification of exhaust gases from burning of high-sulfur coals.

[0031] According to another preferred embodiment, the porous membrane is a non-woven industrial textile, such as a polyphenylene sulfide (PPS) textile of 520 g/m^2. Further, other examples of non-woven industrial textile comprise polyester and polypropylene textiles.

[0032] As elaborated above, the collector electrodes 2 are made of a substantially porous membrane. Upper parts of the vertical tubular collector electrodes may be continuously wetted. Due to capillary action and gravimetrical transport, a water flow may be established within the porous collector electrode, but also at its inner surface as a falling water film. Thus, precipitated and absorbed matter may be transported to the lower end of the vertical collector electrode by a falling water film. Compared to solid vertical tubular collector electrodes, the collector electrodes described herein allow for a larger water flow, whereby more efficient transport of absorbed matter may be achieved.

[0033] As the water flow at the inner surface of the tubular collector electrode 2 typically is counter directional to the flow of the gas to be purified, efficient absorption may be achieved over in principle the entire length of the tubular collector electrode.

[0034] It is to be noted that the flow of the gas to be purified also may flow downwards through the tubular collector electrodes 2 along with the water flow at the inner surface of the tubular collector electrode. In conventional WESP:s with solid tubular collector electrodes, operating in a downstream manner and proceeded by a scrubber, the precipitation of water drops will contribute to the formation of stable water film gravimetrically transported downwards along the inner wall of the solid tubular collector electrode. Thus, the problem of dry spots and build ups will be lowered if such a conventional WESP is operated in a downstream manner. However, said effect is much less pronounced for a WESP having tubular collector electrodes 2 made of a substantially porous membrane, as disclosed herein. In replacing solid tubular collector electrodes of a conventional WESP, with tubular collector electrodes made of a substantially porous membrane, the WESP may still be operated in a downstream manner although not necessary anymore to prevent formation of dry spots and build ups.

[0035] At the lower end of the vertical tubular electrode 2a, the gravimetrically transported water with precipitated and absorbed impurities may be released from the porous membrane and collected. The wet electrostatic precipitator may thus have conventional means 6 for collecting the released water comprising precipitated and absorbed matter. As an example, the housing may have a receiver 6 as its lower end, arranged under the lower ends of the vertical tubes 2a for collecting the released water comprising precipitated and absorbed matter. Further, the housing may have a dispensing means, e.g. an outlet 7, for removing the collected, released water comprising precipitated and absorbed impurities.

[0036] The removed water may be discharged. However, it is also possible to separate the precipitated and absorbed impurities and re-cycle the water. Thus, it may be necessary to only dispose the precipitated and absorbed impurities. If the water is to be re-cycled, it may be necessary to lower its temperature, such as by use of a heat-exchanger before feeding it to parts of the upper end of the porous collector electrode membrane. The use of a heat-exchanger, will allow for improving the overall process economy of industrial process in which the wet electrostatic precipitator is used.

[0037] As already mentioned, upper parts of the vertical tubular collector electrodes 2 may be continuously wetted to establish a water flow within the porous collector electrode 2 and at its inner surface (as well as its outer surface). The porous membrane may be wetted in various ways. As an example, spray nozzles may be arranged at the upper ends 2b of the vertical tubular collector electrodes. However, use of the spray nozzle may imply that water mist is swept away with the gas leaving the vertical tubular collector electrodes. In some applications this may be disadvantageous.

[0038] According to an embodiment, the wet electrostatic precipitator has a horizontal arranged header plate 8 demarcating a space 10 at the upper end of the housing. The upper ends 2b of the tubular collector electrodes may extend above the header plate through openings, typically being essentially circular, in the header plate 8 into the spacing 10 demarcated by the header plate. Alternatively, the upper ends 2b of the tubular collector electrodes 2 may end at openings in the header plate 8. As the upper ends 2b of the tubular collector electrodes extends into, or end at, the spacing demarcated 10 by the header plate, the gas outlet 5 for discharging the purified gas may typically be arranged in communication with the spacing. Alternative, the gas inlet 4 may be arranged in communication with the spacing. The diameter of the openings of the header plate 8, if being circular, may be adopted to provide a close fit around the tubular collector electrodes 2.

[0039] The header plate 8 is typically impermeable to water. Further, the header plate 8 is attached to the housing. By supplying water to the upper side of the header plate 8, a water layer at the upper side of the header plate 8, wetting the porous membrane, of which the tubular collector electrodes 2 is made, may be accomplished. As the tubular collector electrodes 2 are made of a porous membrane, the water flow at the inner surface of the tubular collector electrodes may be accomplished by wetting of the outer surface of the tubular collectors. As a consequence, there is no need to firmly seal off the openings of the header plate 8 through which the tubular collector electrodes extend. However, preferably most of the water wetting the tubular collector electrodes will wet the tubular collector electrodes by overflowing the tubular collector electrodes at their upper ends 2b.

[0040] According to an embodiment, the gas inlet 4 is arranged above the lower open ends 2a of the tubular collector electrodes 3, but below the header plate 8. Thereby, the gas to be purified will flow downwards along the exterior surface of the tubular collectors 2 before entering the tubular collectors 2. As the tubular collectors 2 are made of a porous membrane, also the outer surface of the tubular collectors 2 is wetted. Accordingly, gaseous impurities present in the gas to be purified, such as HC1 and HF, may be passively absorbed also at the water-wetted, exterior surface of the tubular collector 2.

[0041] According to an embodiment, collars 11 are arranged around the openings of the header plate 8 through which the tubular collector electrodes 2 extend in order to have better control of the wetting. Wetting may then be achieved by water overflowing the upper edge of the collar. However, in order to achieve uniform wetting of the tubular collector electrodes, the upper edges of each of the collars have to be at the same distance from the header plate.

[0042] Rather, than wetting the porous membrane, of which the tubular collector electrodes 2 is made, by overflowing, each collar 11 may have at least one opening 12 or cut 22 via which water may flow to wet the porous membrane. As an example such cut 22 may be a slot (cf. Fig. 2), as such as a vertical slot extending from the upper edges of the collar. As long as the upper edge of the collar is not overflown, the wetting will in principle only depend on the size and the number of the openings 12 or cuts 22 in each collar. For slots, the length and the width of the slot as well as the numbers of slots in each collar will determine the wetting rate.

[0043] Although, the entire membrane, around its circumference, eventually will be wetted via capillary action if each collar only has one opening 12 or cut 22, it is preferred if each collar has several openings 12 or cuts 22. By having several openings 12 or cuts 22 arranged separated around the collar, more efficient wetting of the porous membrane may be accomplished.

[0044] Further, although a slot may very well run all the way from the upper edge of the collar to its lower end being attached to the header plate, the length of the a vertical slot may typically be shorter than the height of the collar. Further, although preferred, the slot does not necessarily have to be neither vertical nor linear.

[0045] According to one embodiment (cf. Fig 3), the openings 12 in the collars are arranged at the lower end of the collar close to or at the attachment of the collar 8 to the header plate 8. The degree of wetting may thereby by determined by the number of openings 12 in each collar and their cross sectional area, as well as of the height of the water layer on top of the header plate 8.

[0046] In order to supply water to the upper side of the header plate 8, a water pipe 13 may be connected to the outer side of the housing above the plane of the header plate 8. Further, the water pipe may have means for regulating the rate by which water is supplied. As example, a valve 13a may be arranged on the pipe for regulating the rate by which water is supplied. Although, some of the water supplied may be recycled water, it least part of the supplied water is typically fresh water. Further, as outlined herein above the temperature of the supplied water may be below of the temperature of the gas to be purified.

[0047] The tubular collector electrode 2 will typically have means 2c for mounting it within the housing 1. According to an embodiment, the porous membrane is thus, at the upper end 2b of the collector electrode 2, attached to a ring 2c. The ring may be inserted into a duct of the porous membrane. Such a duct may be formed by folding of one of the ends of the tubular porous membrane. The diameter of the ring 2c may be slightly larger than the diameter of the openings in the header plate 8. Thereby, the tubular collector electrode attached to a ring 2c may be arranged hanging vertically from the header plate, as the ring 2c has a larger diameter than the corresponding opening in the header plate 8. The diameter of the ring 2c may also be chosen to be slightly larger than the diameter of the collar 11, if present. Thereby the collar 11 may act as an abutment for the ring 2c. In addition the porous membrane may also be attached to a ring at its lower. Furthermore, one or several ring(s) may be attached along the porous membrane forming the tubular collector electrode. Having ring(s) attached to he lower end of the porous membrane and/or along the porous membrane, may contribute to achieving a circular intersection of the tubular porous membrane.

[0048] In an embodiment, wherein the openings 12 in the collars 11 are arranged at the lower end of the collar close to or at the attachment of the collar 11 to the header plate 8, it is preferred of the diameter of the ring 2c is smaller than the diameter of the collars 11. In an embodiment, wherein the cuts 12 are vertical slots extending from the upper edges of the collars 11, it is preferred of the diameter of the ring 2c is larger than the diameter of the collars 11.

[0049] According to an embodiment, the tubular collector electrode 2, at its upper edge, is provided with cuts. Such cuts will facilitate the wetting of the porous membrane and the establishment of a falling water film at the inner surface of the tubular collector electrode 2.

[0050] A further advantage with the use of tubular porous membrane as collector electrodes is that they may be installed in an ESP having solid collector electrodes which have been worn out due to corrosion. Installation of tubular porous membranes within the existing solid tubes is far less arduous than replacing the solid tubes.

[0051] As outlined above, the discharge electrode 3 may typically be a wire, a tube or a rigid rod. According to an embodiment, the discharge electrode 3 is a tube having electrode elements that consist of tabs or tongues bent outwardly from the wall of the tube. Such an electrode is described in WO 2003/057371.

[0052] Although the present invention has been described above with reference to specific embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the invention is limited only by the accompanying claims and, other embodiments than the specific above are equally possible within the scope of these appended claims, e.g. different than those described above.

[0053] In the claims, the term "comprises/comprising" does not exclude the presence of other elements or steps. Additionally, although individual features may be included in different claims, these may possibly advantageously be combined, and the inclusion in different claims does not imply that a combination of features is not feasible and/or advantageous.

[0054] In addition, singular references do not exclude a plurality. The terms "a", "an", "first", "second" etc do not preclude a plurality.

Claims

1. Wet electrostatic precipitator for purifying a gas, comprising a housing (1), having an inlet (4) for said gas to be purified, a gas outlet (5) for discharging the purified gas, said housing (1) enclosing a plurality of vertically arranged tubular collector electrodes (2), having open lower and upper ends (2a, 2b), and a plurality of discharge electrodes (3) each being arranged along each of said vertical axis of said tubular collector electrodes (2), said wet electrostatic precipitator having means for wetting the tubular collector electrodes (2) at their upper ends (2b), said electrostatic precipitator having a horizontally arranged header plate (8) demarcating a space (10) at the upper end of said housing (1), wherein the upper ends (2b) of the tubular collector electrodes (2) extend above the header plate (8) through openings in the header plate (8) into the spacing (10) demarcated by the header plate (8), or the upper ends (2b) of the tubular collector electrodes (2) end at openings in the header plate (8), said gas outlet (5) being arranged in communication with said spacing, and said inlet (4) being arranged below the header plate (8), or said inlet (4) being arranged in communication with said spacing, and said gas outlet (5) being arranged below the header plate (8), **characterized in that** said tubular collector electrodes (2) are made of a substantially porous membrane.

2. The electrostatic precipitator according to claim 1, wherein said gas outlet (5) is arranged in communication with said spacing (10), and said inlet (4) is arranged below the header plate (8).

3. The electrostatic precipitator according to claim 1 or 2, wherein said discharge electrodes (3) have spikes or tabs (3a) extending from the discharge electrode (3) and ending in sharp tips.

4. The electrostatic precipitator according to any one of the claims 1 to 3, wherein said gas inlet (4) is arranged above the lower ends (2a) of said tubular collector electrodes (3) and below the header plate (8).

5. The electrostatic precipitator according to any on of the preceding claims, wherein collars (11) are arranged around the openings in said header plate (8).

6. The electrostatic precipitator according to claim 4, wherein each of said collars (11) has at least one cut (22) or opening (12) via which water may flow to wet the porous membrane.

7. The electrostatic precipitator according to claim 6, wherein said openings are arranged at the lower end of the collar close to or at the attachment of the collar (11) to the header plate (8).

8. The electrostatic precipitator according to any on of the preceding claims, wherein said porous membrane at its upper end is attached to a ring (2c), whereby said tubular collector electrode may be arranged hanging vertically from said header plate, optionally further ring(s) are being attached to the lower end of the porous membrane and/or along the porous membrane.

9. The electrostatic precipitator according to any on of the preceding claims, wherein the edge of the upper ends (2b) of the tubular collector electrodes (2) is provided with cuts (2d).

10. The electrostatic precipitator according to any on of the preceding claims, wherein said substantially porous membrane is essentially non-conducting.

11. A method for purifying a gas comprising the step of:

- introducing said gas into a wet electrostatic precipitator according to any one of the claims 1 to 10 via the inlet (4); and
- obtaining a purified gas via the outlet (5);

wherein the temperature of the gas to be purified, as well as the temperature of the purified gas, is above the dew point of the gas; said tubular collector electrodes (2) are being continuously wetted at their the upper ends (2b); and an electrical field is applied between the discharge (3) and collector (2) electrodes.

12. The method according to claim 11, wherein the temperature of the water applied to the upper ends (2b) of said tubular collector electrodes (2) is below the dew point of the gas to be purified.

13. The method according to claim 11 or 12, wherein the temperature of the water applied to the upper ends (2b) of said tubular collector electrodes (2) is 10 to 30°C.

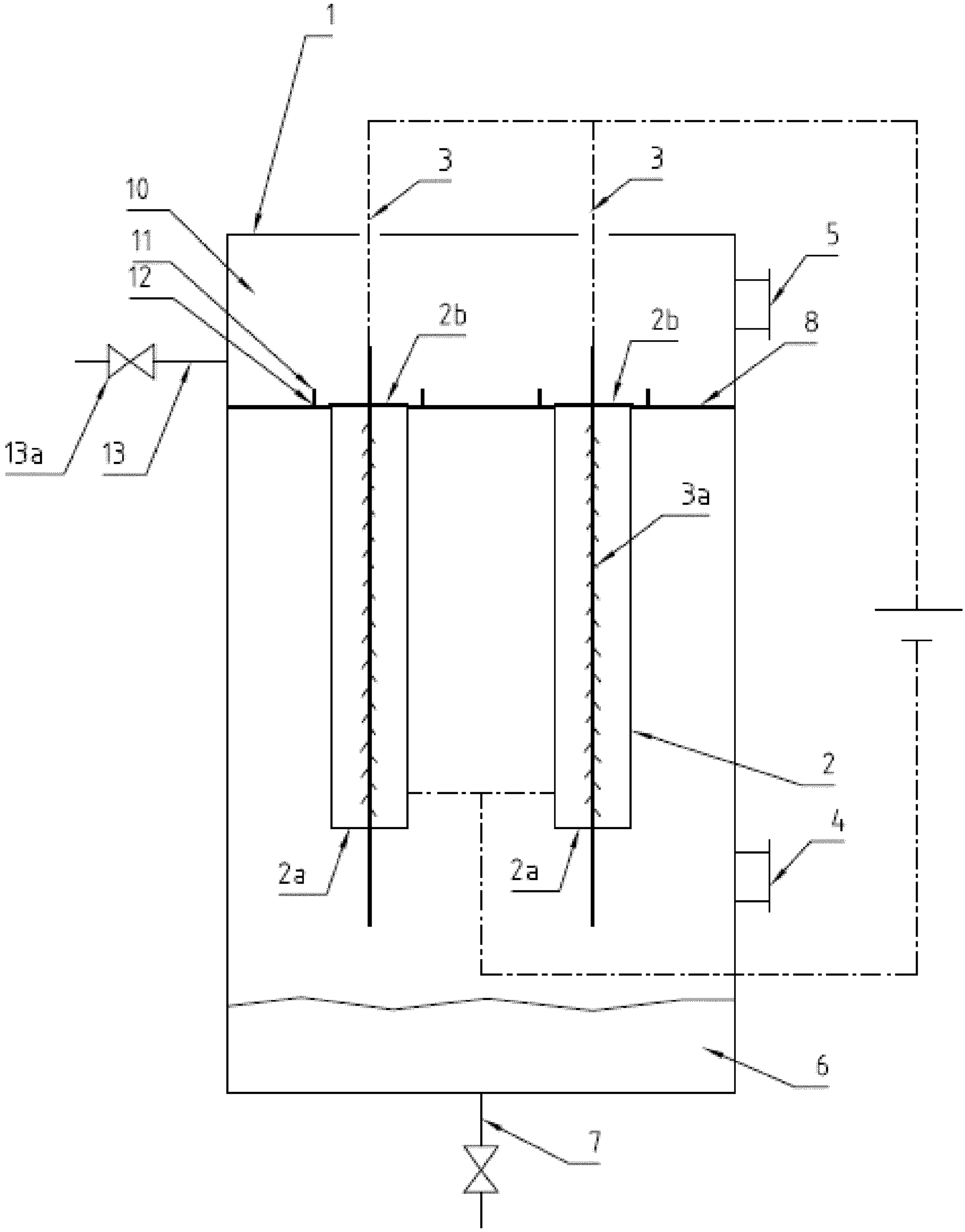

Fig.1

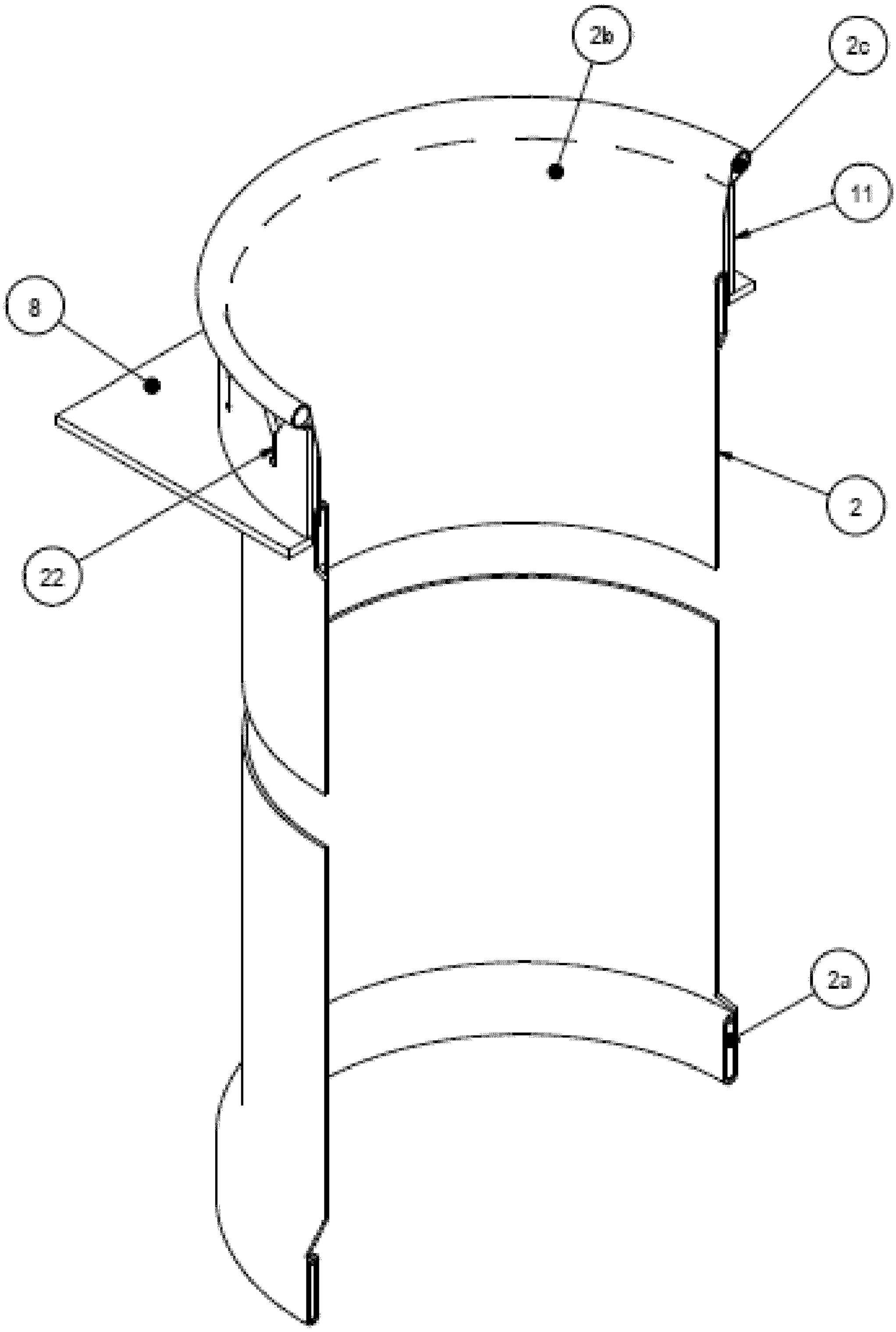

Fig 2.

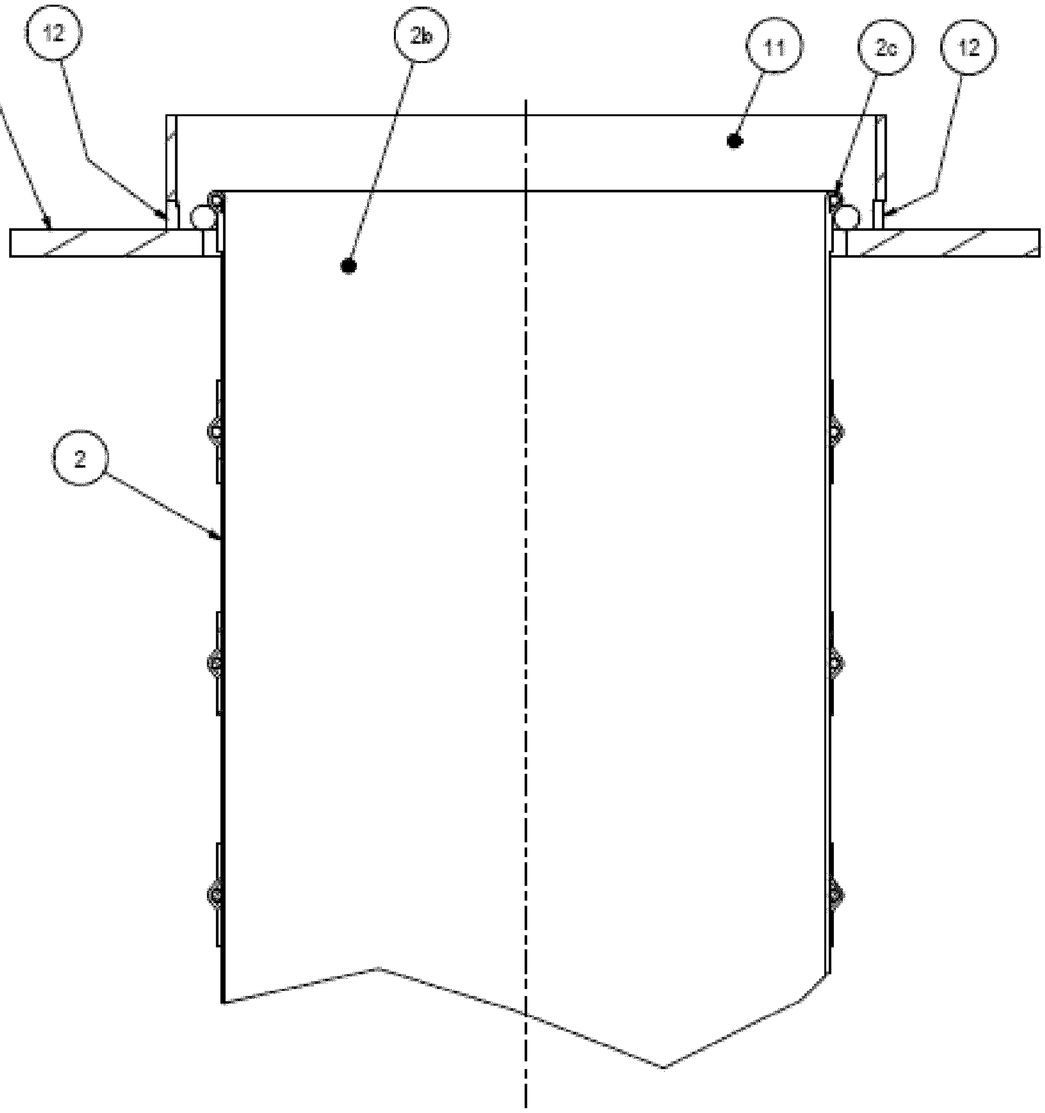

Fig. 3

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	19 June 2012	Menck, Anja

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1

Place of search	Date of completion of the search	Examiner
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