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(54) **ELECTROSTATIC PRECIPITATOR**

ELEKTROSTATISCHER ABSCHEIDER

DÉPOUSSIÉREUR ÉLECTROSTATIQUE

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Description

[0001] The present invention relates to an Electrostatic precipitator as stated in the preamble of claim 1.

[0002] More precisely, the invention relates to precipitation of harmful substances and dust from flue gas, which develops during incineration of fuel in an incinerator, or of particles in emission from production.

[0003] Incinerators are known and are widely used. An incinerator develops heat by burning fuel. The fuel can be raw material or a waste product.

[0004] Out of consideration for the surrounding environment it is desired that the fuel is converted as completely as possible and without developing toxic substances. Controlling the air supply and the combustion temperature has a great influence on the development of toxic substances. Toxic substances, which are developed during the incineration, are retained in the slag or are released into the environment with the flue gas/emission.

[0005] As the public wish for a transition to sustainable resources increases, a search for alternative fuel is commenced. For instance it has been endeavored to use rapidly growing crops such as elephant grass or willow chips. Husks or grain from rye, barley, triticale or rapeseed are also examples of utilized fuel types. The residual product straw from growing of cereal has also been attempted used as fuel.

[0006] It is given that some of the abovementioned fuel types are more suited for burning than others. Burning of straw generates good heat but unfortunately a large emission of dust consisting of fine and ultra-fine particles of the size 0,1 to 1 μm. As these particle sizes are suspected of causing lung damage it is a wish to lower or if possible remove the emission of particles into the surroundings. This is supported by impending legal requirements where it is expected that the limit will be set as low as between 20 - 40 mg/nm3 at 10% oxygen.

[0007] Removal of particles can efficiently be done with a scrubber, filter, for instance as a bag, or by means of an Electrostatic precipitator. Using a scrubber has disadvantages in terms of the form of the residual product and the surrounding environment, including expenses for water and chemical remedies. Further, the residual product, which is aggressive in the liquid state, makes large demands on choice of material for the equipment, as the equipment otherwise would be corroded quickly. Bag filters cause a large pressure loss and have a lower efficiency. The pressure loss increases rapidly as particles accumulate in the bag, which affects the operational reliability in a negative manner. Scrubbers and bag filters are also relatively expensive solutions both in terms of installation and operation, which is why it would be desirable to find an effective alternative for use in an Electrostatic precipitator, if it can be brought into use and can achieve a better efficiency and operational reliability in addition to being economical.

[0008] Basically, an Electrostatic precipitator consists of an air lock in which electrodes in the form of anodes are located, typically consisting of conductive threads with an electrode counterpart of conductive metal plates, which form a cathode. The anode and the cathode are connected to a power supply which supplies a voltage in the region of 20 to 100 kV. The power supply comprises a transformer and a rectifier circuit such that a pulsating or a direct voltage is achieved. The direct voltage can also be overlaid by a short pulsating voltage in order to better be able to penetrate the layer of dust. The particles are ionized when passing by the electrical field and are attracted by the conductive metal plate, which constitutes the cathode, and can be removed in a relatively simple manner e.g. by beating on the plate, which must be done regularly.

[0009] As for Electrostatic precipitators, these are highly efficient for removing dust including fine and ultra-fine particles. For that reason Electrostatic precipitators are commonly used in the industry and in waste incineration. In regular waste for incineration the flue gas contains the entire spectrum of particle sizes and since the dust also contains some carbon the cathode plate will retain its effect even when a layer of dust has accumulated thereon. This is due to the fact that the layer of dust in the same manner as the cathode plate has electroconductive abilities.

[0010] The fine and ultra-fine particles, which are formed as a result of burning of straw however, consist for a large part of potassium chloride and are both lightweight and very resistive, i.e. electrically insulating, for which reason the effect of the Electrostatic precipitator quickly decreases. This is owing to the fact that the cathode plate is quickly filled with ultra-fine and light dust, which cannot be beaten off the plates. Further, the dust is pressed so hard together on the cathode plate that it is difficult to remove. It is thus commonly known that Electrostatic precipitators are not regarded as suitable for cleaning of smoke from burning of straw or the like. A further disadvantage is that the power supply is stressed, when the electrically insulating layer of dust and thus the reflection effect result in flashovers and short circuit of the power supply.

[0011] In order to solve the problem it has been attempted to supplement with other fuel types, e.g. wood chips, which improves the smoke cleaning of the fine and ultra-fine particles in that these will lump to the larger particles, which can be removed more easily from the filter by beating. Despite the fact that this in an improvement the problem with insulation of the cathode plate is still not solved as the fine and ultra-fine particles continue to accumulate on the cathode plate.

[0012] Based on the outlined disadvantages a solution for improving the continuous cleaning ability of an Electrostatic precipitator when the flue gas contains large amounts of resistive fine and ultra-fine particles is desired.

[0013] It is furthermore desired to provide a simpler and more compact system with the advantages connected therewith, but also with a view to cheaper production and transportation to the installation location.

[0014] The purpose of the invention is to disclose an Electrostatic precipitator, which is more compact but continuously is effective in removing fine and ultra-fine resistive particles from flue gas or emission.

[0015] This is achieved according to the invention by designing the Electrostatic precipitator as stated in claim 1 in that the Electrostatic precipitator comprises:

- a cabinet with:
- an inlet for inflow of flue gas;
- an outlet for outflow of cleaned flue gas;
- a mounting arranged between inlet and outlet adapted to carry a rotatable shaft, on said shaft is arranged a number of parallel electroconductive plates, which are adapted to function as cathodes;
- a motor for rotating the rotatable shaft;
- an arrangement for retaining a number of conductive threads, which function as anodes and for arranging these threads such that they are led through the area between the cathode plates;
- a power supply with connection for anode and cathode, where the Electrostatic precipitator comprises at least one plate (14) with a number of holes (16) for passage of flue gas, wherein said at least one plate (14) is arranged in a position between the cathode plates (7) and comprises slots for lead-in of the cathode plates (7), such that the flow of flue gas during passage through the holes is regulated and distributed evenly between the cathode plates.

[0016] Studies of prototype Electrostatic precipitators have shown that the distribution of the flue gas through the Electrostatic precipitator has a huge impact on the further operation of the filter, as temperature differences will cause the metallic parts to deform. In particular it has been noticed that the cathode plates, which for practical reasons in order to be able to rotate about their axis within the cabinet are circular, buckle at an uneven heat distribution. A high temperature at the middle of the Electrostatic precipitator in the centre of the cathode plates compared to the periphery of the cathode plates will mean that the cathode plates are exposed to internal mechanical tension which causes them to deform. At best the discs will become slightly crooked or uneven. At worst they will become saucer-shaped. This can be entirely or partially in a section. This presents a big challenge in connection with maintaining a short distance between anode and cathode and avoiding flashovers or outright short-circuiting. When a flashover occurs it drastically reduces the efficiency of the Electrostatic precipitator and can cause breakdown of the filter. Another disadvantage is that it is difficult to remove dust, which is attracted by the cathode plate from crooked or saucer-shaped cathode plates as an adapting scraper is difficult to manufacture. Further a better efficiency of the filter is achieved when the flue gas is distributed more evenly throughout the filter.

[0017] The solution according to the invention, which through regulating, distributing and dividing the flow of the flue gas from inlet to outlet in order to ensure a uniform temperature distribution in the Electrostatic precipitator to avoid deformation of the cathode plates, can comprise one or more screens inserted into the inlet for inflow of flue gas into the Electrostatic precipitator. The screens can thus divide the flow of the flue gas into layers or sections and guide the flow in the right direction such that the flue gas is distributed with the same pressure and thus temperature in the entire cabinet.

[0018] Expediently, the distribution plates are inserted in more sections. A first section where the flue gas is introduced through a tube from the incinerator where an inlet is shaped as a funnel and where plates are arranged in the funnel for spreading or distributing the flue gas such that the flue gas at the outlet of the funnel is distributed evenly over the entire area of the outlet. It is understood that the funnel shape receives the flue gas at that end of the funnel with the smallest cross-section area and releases the flue gas at that end of the funnel with the largest cross-section area. In the first section the inlet funnel thus divides or separates the incoming flow into a number of sections. The area of the outlet can reflect the internal width of the cabinet. Thus, the inlet funnel functions as a transition between the exhaust tube from the cross-section area of the incinerator to the outlet of the area of the funnel, where the cross-section area of the exhaust can be can be adapted to a height or width dimension of the filter. In an embodiment the outlet of the funnel-shape is adapted to both a height and width dimension of the filter. Thus, an even distribution of the flue gas flow through the filter is ensured. More precisely a pressure drop occurs during the flow of the flue gas in the inlet funnel in that the flow of the flue gas is spread out over a larger area. The dimensions of the outlet tube of the incinerator aim at keeping the speed of the flue gas during maximum output at a maximum of 25 meters pr. second. Experience shows that a speed of the flue gas between 13 and 20 meters pr. second gives a good efficiency of the incinerator without causing turbulence in the flow of the flue gas. Turbulence is undesired as it leads to a larger resistance against the free flow of the flue gas and results in sedimentation of particles which in the long term can clog the tube. It is a wish that the particles are transported with the flue gas to the filter and are not released from the flue gas until that time as it otherwise would be necessary to beat the particles loose or use a soot blowers. By the flue gas flowing through the inlet funnel the pressure ratio will change as a result of the gradually larger cross-section area of the funnel and cause the speed of the flue gas to be lowered. The proportions between the area of the funnel between its inlet and outlet should be dimensioned such that the speed of the flue gas in the filter is lowered to a value below 2 meters pr. second, which ensures that the particles have such a suitable low speed in the filter that the attraction by the cathode plates on the loaded particles is bigger than the kinetic energy they are influenced by in the flue gas flow. This gives the filter a good efficiency. The dividing plates help divide the flow into separate flows, which has the advantage that the inlet funnel can have a shorter course. The hydraulic area of the tube-shape is divided by inserting plates or screens by which the new channels have their own hydraulic area. The division in the inlet funnel can expediently be done in a vertical direction such that the flow of the flue gas is spread out from a relatively modest tube size of between 100 to 400 mm in the exhaust tube to the entire width of the filter cabinet. Thus, at the outlet of the funnel, the flue gas is led in a vertical direction either in an upward-going direction or most commonly due to the height and natural exhaust at the topmost part of the incinerator, in a downwards direction in the cabinet for the filter inlet. The flow of the flue gas is in the vertical course at different horizontal heights divided into segments or layers by insertion of screens at different horizontal heights in order to separate and channel a portion of the flow of the flue gas into the cabinet for the filter in a horizontal direction. In an embodiment the screens, which divides the flue gas into segments in the horizontal plane, are arranged in the inlet funnel. In another embodiment they are arranged after the inlet funnel in the cabinet of the filter in the area before the electrically active electrode parts. The screens should be dimensioned such that the division of the flue gas ensures a homogenous speed of the flue gas over the entire area of the inlet of the filter, as it is thus prevented that the cathode plates become crooked due to uneven heat impact. A somewhat higher flue gas flow in the central area can however be desired, as the stroking of the cathode plates here has a longer course. This will result in a better efficiency of the filter.

[0019] The inlet funnel thus serves the purpose of changing the flow of the flue gas to a wider flow while still ensuring that the flue gas has a homogenous speed throughout the flow. In an embodiment this takes place in the vertical course. Furthermore, a number of screens are instated into the inlet in the cabinet for the filter, which divides and distributes the flow of the flue gas in the horizontal plane in the cabinet for the filter before the flue gas is led past the anode and the cathode electrodes in the Electrostatic precipitator.

[0020] The number of screens in the vertical direction and in the horizontal direction and their spreading and location is determined by the difference between the hydraulic area of the inlet tube from the incinerator and the hydraulic area of the filter for flow of flue gas in terms of the speed of the flue gas. The dimensioning must be done based on a wish that the flue gas flow from the incinerator is distributed through the Electrostatic precipitator in a homogenous flow throughout the entire course of the Electrostatic precipitator.

[0021] The distance between the dividing plates is thus calculated based on the hydraulic area in each section and the speed profile of the incoming flow. At a higher inlet speed of the flue gas the incoming flow has a more flat profile, whereas it is more dish-shaped at a lower speed.

[0022] This structure ensures a homogenous speed of flue gas in the cabinet where the aim is that all cathode plates are stroked by the same amount of flue gas and on both sides of the cathode plates. The flue gas is let in from above and directly downwards towards the bottom of the cabinet but can also be let in from other angles, e. g. from the sides or the bottom. Since the flue gas is hot it will rise upwards. For that reason inlet from the top towards the bottom is advantageous. In order to further ensure the spreading of the flue gas in the entire height of the cabinet, plates are inserted at various heights in the cabinet, which distribute the flow of flue gas from the inlet in a mostly horizontal direction. It is understood that in order to ensure that the flue gas also is distributed at the bottom of the cabinet the screens can be angled such that they regulate the flue gas downwards towards the bottom. This counteracts the tendency of the hot flue gas to rise upwards towards the top of the cabinet as a result of thermodynamics. Further, the invention comprises another step, which is adapted to regulate the spreading of the flow gas in the cabinet. To obtain a better regulation and distribution of the flow of flue gas through the Electrostatic precipitator, the Electrostatic precipitator in an embodiment comprises at least one plate with a number of holes for passage of flue gas, arranged at a position between inlet and outlet such that the flow of flue gas during the passage through the holes is regulated and distributed evenly between the cathode plates. An analysis of the flow of flue gas through the Electrostatic precipitator at various loads can determine a precise dimensioning of the holes and their location. More plates can be inserted into the cabinet at desired positions and angles in order to regulate the direction and the distribution of the flue gas with a view to achieving an even temperature distribution in the cabinet.

[0023] It is noted that the flow of the flue gas further serves the purpose of obtaining a disposition of flue gas which is as large as possible for the electrical field between the anode and cathode electrodes and thus obtaining a better cleaning ability of dust in the filter.

[0024] According to the invention, the device comprises at least one plate with a number of holes for passage of flue gas arranged at a position between the cathode plates such that the flow of flue gas during passage through the holes is regulated and distributed evenly between the cathode plates. This position is desirable as the distribution of the flue gas is particularly important over the surface of the cathode plates in order to avoid temperature differences over the surface of the plate and resulting mechanical tension and crookedness. In a typical embodiment thereof the plate is arranged in the cabinet in a vertical direction compared to the flow of the flue gas from inlet to outlet through the Electrostatic precipitator.

[0025] It will be appreciated that the size and location of the holes are organized with a view to an even distribution of the flue gas between the cathode plates. This can in part be ensured by measuring on specific embodiments. Further, simulation programs can be used in connection with specific designs.

[0026] The device consisting of the plate for regulating the flow of flue gas is equipped with recesses or grooves where at least part of the cathode plates can be led through.

[0027] In another embodiment a dividing plate is arranged in connection with, preferably on top of or behind, the device consisting of the plate for regulating the flow of flue gas. The dividing plate is mounted over the opening(s) in the plate for regulating flue gas. This means that the device consisting of the plate for regulating the flow of flue gas can be designed with one or more lead-ins, which are covered by the distributing plate. It is thus easier and simpler to adapt a regulation of flow of flue gas to the specific application and use. It is possible to conduct a measuring of the flow of the flue gas through the filter and afterwards calculate and design a distributing plate for mounting on top of the plate for regulating the flow of flue gas, said distributing plate optimizes the function of the Electrostatic precipitator for the specific purpose.

[0028] In an embodiment the device consisting of the plate for regulating the flow of flue gas is in itself or with an attached distributing plate retained relative to the cabinet, but is in movable contact with at least one cathode plate arranged on the rotatable shaft and is adapted to function as a scraper at contact with the cathode plate.

[0029] In another embodiment the device is equipped with a folded down edge, where the edge functions as a scraper. Expediently, the scraper is made from a flexible material and arranged resiliently suspended in contact with the cathode plate. To achieve a good scraping effect the scraper is arranged in contact with the cathode plate is such a manner that the folding of the edge is constructed such that the edge forms a sharp angle towards the direction of rotations on the cathode plate and thus functions as a cutting blade during the rotation of the cathode plate. As mentioned above the cathode plate is rapidly packed with the fine and ultra-fine dust particles, which constitute a hard layer, which is electrically insulating, for which reason the effect of the Electrostatic precipitator rapidly decreases. A layer of 0,1 mm is thus enough to lower the efficiency of the ability of the cathode plates to attract dust and in practice render the Electrostatic precipitator useless. Tests have shown that the surface structure of the cathode plates is a big part of the explanation as to why the fine and ultra-fine particles bind themselves so hard to the plate. Seen under a microscope the plate is, in correlation with the fine and ultrafine particles, rough and filled with small holes and protrusions with fine structures in which the fine and ultrafine particles can accumulate. The cathode plate cannot be completely cleansed of the fine and ultra-fine particles by scraping, for which reason a fine, thin and ultra-hard layer of approximately 0,001 mm remains. Very surprisingly it has proven that the ultra-hard thin layer is not electrically insulating, but has by and large the same efficiency in terms of capturing particles as a new and unused cathode plate. It has proven that this effect is also obtained by compression of the fine, thin and ultra-hard layer. Concrete measurings have proven that an embodiment of a scraper which presses against the cathode plate with a force of more than 5 N/cm has an adequate effect for removing the main part of the fine and ultra-fine particles, which have accumulated on the cathode plate and for compression of the remaining thin layer.

[0030] In an embodiment the scraper contains fine-grained corrosion-resistant steel of the type known as "304". A plate thickness between 0,5 and 2 mm has proven to be suitable, whereas a thickness of 0,7 mm has proven most suitable for achieving the desired resilient effect. The scraper has proven very functional with a folded down edge of 40 mm when the plate has a thickness of 0,7 mm. However, a folded down edge of between 10 to 100 mm can be anticipated, depending on choice of material, plate thickness and distance to the cathode plate.

[0031] In an embodiment the scraper is arranged in the side of the cabinet, which faces towards the inlet. When the particles are removed there is a risk that the flow of flue gas will whirl the fine and light particles upwards before dropping down into a collection unit at the bottom of the cabinet. As the scraper is arranged in the inlet the filter can handle any particles which are scraped off the cathode plate and whirled upwards by the flue gas and capture these particles again, thus minimizing the amount of particles which are released into the outlet.

[0032] In yet another embodiment the scraper is arranged in contact with the lower half-circle of the cathode plate. By only scraping particles off the lower half-circle it is avoided that the particles have a long fall distance towards the collection unit at the bottom of the cabinet. This minimizes the amount of particles which are whirled upwards and thus the amount of particles which are released into the outlet.

[0033] Cathode plates are made from an electro-conductive material, which can e.g. be metallic or ceramic. The material must be suited for withstanding the temperatures to which it is exposed in the Electrostatic precipitator.

[0034] In an embodiment the cathode plates are made from close-grained alloyed steel, which is corrosion-resistant in that especially the chrome content in the alloy forms a protective surface which is still electro-conductive. A trade name for the chosen steel type is "Cor Ten". It is also known under the English term "weathering steel" as it is used for facades of buildings and is known for its rusty red patina. A commercially available product, which is applicable for cathode plates, is CORTEN A EN 10025-5 or Cor-Ten A/S355 JOW.

[0035] A suitable quality steel plate has a roughness of 2B with a Ra of approximately 0,3 micrometers and a

Rz of 2,9 micrometers.

[0036] In an embodiment the cathode plates have a thickness between 3 and 12 mm where a particularly appreciated thickness is 6 mm. This thickness is relatively easy to process and has so much weight and thermal conductivity that it is simpler to avoid or minimize mechanical tension which can lead to crookedness or saucer-shape. The diameter of the plate can in an embodiment be between 30 cm and 300 cm. In a particularly appreciated embodiment the plate thickness is set at 6mm with a diameter of 150 cm.

[0037] Furthermore, it has been proven that a cathode plate made from close-grained alloyed steel (COR TEN A) and a scraper made from fine-grained corrosion-resistant steel (304) have good concurrent properties when it comes to removing particles from the cathode plate. Since the scraper is made from a softer material this will be worn more than the cathode plate and not leave marks on the cathode plate. When the scraper gets so worn that it no longer pushed with the necessary force against the cathode plate it is relatively easy to replace with a new and in-expensive scraper. The scraper, which is made from fine-grained corrosion-resistant steel (304), further has good elastic and resilient properties, which ensure that the scraper continuous can be in resilient contact with the cathode plate. If the scraper is arranged such that the elastic force against the cathode plate is 5N/cm, tests have shown that the scraper functions optimum. An elastic force between 2N/cm and 10N/cm has an acceptable effect. An elastic force of more than 5N/cm is efficient but also causes more wear on the scraper and cathode plate.

[0038] Since the ability of the cathode plate to attract particles is determined by the electro conductivity of the cathode plate, and the ability for cleaning is based on the smoothness compared to the particles, a special embodiment is conceived. A metal plate is in its nature rough and has a surface filled with small protrusions and small depressions, where there are cracks and small holes in protrusions and depressions. The fine and ultra-fine particles are captured and are difficult to remove from these cavities again. To make the surface smooth and thus avoid that particles are captured in cavities the plate is in an embodiment a corrosion-resistant steel plate, which is electropolished. Electropolishing is a treatment of the surface of a metal plate with a combination of chemistry and electrical impact, after which the plate appears smooth and shiny.

[0039] In another embodiment the cathode plate is covered or coated with an electroconductive coating. The electroconductive coating can be metallic or ceramic or a combination thereof. A coating which consists of smaller particles than the fine and ultra-fin particles which should be collected is particularly suitable, as the fine and ultra-fine particles by virtue of their size will experience difficulties in sticking to the surface. A coating of the cathode plated with an electroconductive ceramic coating of nanoparticles is thus a suitable solution.

[0040] A cathode plate with a surface coated with nanoparticles will thus be easier to clean by which the scraper is made redundant and can be replaced with a brush with hair of a heat-resistant material. The hairs of the brush can e.g. be made from copper, brass, steel but also for instance ceramic fibres.

[0041] Measurings have further shown that the design of the edge of the cathode plate has an impact on the efficiency of the Electrostatic precipitator. It has thus proven that a cathode plate with a curved edge is more dismissive of flashovers. Flashovers tend to emanate from sharp edges and protrusions. During operation a layer of particles can accumulate on the edge of the cathode plate. Even though the area of the edge is insignificant compared to the area of the cathode plate it has proven that cleaning of the edge has an impact on avoiding flashovers and that the efficiency of the Electrostatic precipitator is increased by keeping the edge clean. Thus, in an embodiment, the Electrostatic precipitator comprises a scraper arranged in the cabinet in a position where this is in contact with the edge of a cathode plate and is adapted for keeping the edge free of particles during rotation of the plate. In an embodiment the scraper is specifically adapted to function as a scraper against the curved edge of the cathode plate by being designed with a corresponding curved shape, adapted for being able to scrape the entire half-circle of the curved edge of the cathode plate when the cathode plates are rotated.

[0042] The scraper can be made from or contain at least one of the following materials: steel, iron, aluminum, copper, brass, ceramic.

[0043] In another embodiment the scraper is designed as a brush with hairs, which contain a heat-resistant material such as copper, steel, fibre of glass etc.

[0044] Further characteristics of the invention will appear from the following embodiment of the invention, which is described more fully below with reference to the accompanying drawing, in which:

Fig. 1 shows a cabinet with an Electrostatic precipitator seen from the front,

fig. 2 shows a cross-section A-A seen through the cabinet,

fig. 3 shows a cross-section B-B seen through the cabinet,

fig. 4 shows a distribution screen for inlet,

fig. 5 shows a section C-C seen through the inlet,

fig. 6 shows a distribution plate for adjusting the flow through the cabinet,

fig. 7 shows a profile of the edge of a distribution plate, which functions as a scraper,

fig. 8 shows an enlarged view of the surface of a cathode plate,

fig. 9 shows an enlarged view of the surface of a cathode plate with particles,

fig. 10 shows an enlarged view of the surface of an electropolished cathode plate, and

fig. 11 shows a detail of the edge of a cathode plate and a scraper therefor.

[0045] As it appears from Fig. 1 of the drawing, which shows a cabinet 2 for an Electrostatic precipitator 1, an inlet 3 is shown at the left, where the flue gas, which should be cleaned of particles, is supplied. The cleaned flue gas is led out of the cabinet via an outlet 4 and further on to a chimney (not shown). At the front of the cabinet there is an operating device 5 and a motor drive 6 with a gearing. The motor drive 6 rotates cathode plates 7 as shown in fig. 2 which shows a section through the longitudinal direction of the cabinet 2. The cathode plates are suspended on a shaft 8, which are arranged in a bearing 9 in both sides of the cabinet 2. As anode a number of metallic strings 10 are suspended in a frame 11, said frame is secured at the top and bottom of the cabinet 2 and keeps the strings stretched such that they will not collide with or get too close to a cathode plate 7 as this could otherwise result in flashover.

[0046] If the flow of the flue gas through the filter is analyzed it will be noticed that the spreading of the flue gas will follow the course with the least resistance. This means that a non-regulated flue gas will move towards the centre of the cabinet 2 in an upward-going flow, the direction of which is dependent on the speed of the flue gas, which is determined by the effect of the incinerator in relation to the discharge conditions for the flue gas, particularly the pressure loss in tubing, filter and chimney. The efficiency of the filter without regulation of the flow of the flue gas is thus not optimum. Further, the parts which are located in the part of the flue gas flow, which can be denominated the plume of smoke, are heated more than the other areas in the cabinet which entails a risk of tension and deformation of the materials, where particularly a deformation of the cathode plates 7 is problematic in connection with cleaning thereof.

[0047] It is thus important for the dimensional stability of the cathode plates 7 that the flue gas is distributed evenly in the cabinet 2 such that the temperature distribution in the cabinet is not too great. If the temperature of the cathode plates is uneven throughout the spreading they will buckle and it will be difficult to keep them clean. There will also be a greater risk for flashovers between anode strings 10 and cathode plates 7. In order to ensure a homogenous heat distribution in the cabinet 2 the inlet 3 is equipped with screens 12, which regulate distribute and divide the flow of the flue gas from inlet 3 towards the surface of the cathode plates 7. A detailed view of a screen according to the invention is shown in fig. 4. As it further appears from fig. 5, which shows a section in inlet 3, the inlet is equipped with a number of plates 13, which distributes the smoke in the inlet over the entire width of the filter. Thus, a homogenous speed of the smoke through the filter without turbulence and also a homogenous heat distribution in the entire filter is achieved. Since the cathode plates 7 are not constantly rotated but only at intervals in order to clean the plates, achieving an even heat distribution through the filter is important, as the cathode plates otherwise risk buckling due to uneven heating and becoming irreversibly crooked. If the cathode plates 7 become crooked it will mean that the cathode plates will become difficult to keep clean with a scraper and that the distance between anodes and cathodes are changed which can cause flashovers in the power supply and breakdown of the filter.

[0048] To further ensure a good heat distribution through the filter a smoke plate 14 (shown in Fig. 2 and 3) is inserted from top to bottom in the cabinet 2, where slots 15 are provided for lead-in of cathode plates 7. Further the smoke plate 14 is equipped with holes 16 of various sizes which each are adapted to regulate flow of flue gas such that a homogeneous speed of the smoke and temperature distribution in the entire cabinet 2 is achieved. This also ensures that the cathode plates 7 are evenly and homogenously stroked by the flue gas by which electrically loaded particles are deposited on the cathode plates.

[0049] On the smoke plate 14 in the cabinet 2 distribution plates 17 are inserted between the cathode plates 7 for adjusting the flow of the flue gas through the cabinet 2 from inlet to outlet. A detailed drawing of a distribution plate 17 according to the invention is shown in Fig. 6, where a number of through-going holes 18 are shown. The holes 18 are arranged in a row but the embodiment should not be considered limiting to the invention as the holes with their size and position are configured to provide an even flow through the cabinet which ensures a homogenous heat distribution. The location and size of the holes can thus be randomly positioned based on tests or calculations in order to facilitate an even heat distribution in the cabinet and prevent the cathode plates from becoming crooked due to an uneven heat distribution. As it can be noticed from fig. 7, which shows a cross-section of a distribution plate 17 this is equipped with a folded down edge 19 on both sides. The width of the distribution plate 17 is so large that when this is mounted between the cathode plates 7 the edge constitutes a scraper 20 against the cathode plates 7 which flank the distribution plate 17 on both sides. The dimensioning of the distribution plate 17, including the width of the plate and the material thickness as well as the fold angle of the scraper-part determines its resilient abilities against the cathode plates 7. Thus, an appropriate elastic force can be determined. A value of 5N/cm is appropriate.

[0050] A scraping of the cathode plates 7 is desired, which removes the particles, which is attracted by the electrical field, but the scraping should not be so hard that the cathode plates 7 and the scrapers 20 are worn too quickly. This is achieved partly by the choice of material where the cathode plates are made from COR TEN A steel (close-grained steel) and scrapers 20 on the distribution plate 17 are made from corrosion-resistant fine-grained steel as type 304.

[0051] Fig. 8 shows a microscopic view of a cross-section of the surface of a cathode plate 7. As it appears the plate has a certain roughness, which resembles a mountain or hill landscape 21. Since the roughness is larger than the particle size of the particles which should be collected, the particles will quickly fill the cathode plate 7 with electrically insulating dust, which prevents the further operation of the Electrostatic precipitator 1. Fig. 9 shows a microscopic view where the cathode plate 7 has gathered a layer of particles 22. Because of the peaks, a scraping cannot remove all particles 22 and reestablish the full original function of the Electrostatic precipitator. However, it has proven that the pressure, which the scraper 20 exerts on the thin layer of particles of approximately 100 micrometers, makes the layer more electroconductive such that the cathode plate 7 again can attract new particles 22.

[0052] Despite the fact that this seems satisfactory and is cheap to manufacture, it is expedient that the cathode plate 7 is as smooth as possible, such that the cracks, bumps and indentations 21 which are present in the surface, are smaller than the size of the particles 22, which are attracted to the cathode plate 7. If a cathode plate 7 of a corrosion-resistant material is chosen, this can be polished, possibly electropolished, such that the surface becomes completely smooth which is illustrated in fig. 10. It is also possible to make the cathode plate smooth by applying an electroconductive layer, a coating. This can be a ceramic coating with conductive nanoparticles. As the particles 22 in the flue gas, which are attracted to the cathode plate in the electrical field, are larger than the particle size of the coating of the cathode plate, they will not be able to bind as hard to the cathode plate 7 and thus be easier to remove, for instance by means of a brush.

[0053] As part of the invention, as shown in Fig. 11, a cross section of a cathode plate 7 is shown, where the edge 23 thereof is visible. As can be seen, the edge 23 is curved as tests have shown that many flashovers emanate from the edge, and it has proven that the curved shape better counters flashovers. Tests also show that an accumulation of dust particles on the edge can cause more flashovers. Therefore according to the invention a scraper 24 is devised, which is arranged in the cabinet 2 in such a manner that it strokes or scrapes the edge 23 of the cathode plate 7 and keeps it clean. As it appears the scraper 24 is equipped with a recess 25, which is curved and which reaches over the curvature of the edge 23 for which reason the cathode plate 7 is kept clean when it rotates.

Claims

1. Electrostatic precipitator comprising:

- a cabinet (2) with:
- an inlet (3) for inflow of flue gas;
- an outlet (4) for outflow of cleaned flue gas;
- a mounting arranged between inlet and outlet adapted to carry a rotatable shaft (8), on said shaft is arranged a number of parallel electroconductive plates, which are adapted to function as cathodes (7);
- a motor (6) for rotating the rotatable shaft (8);
- an arrangement (11) for retaining a number of conductive threads (10), which function as anodes and for arranging these threads such that they are led through the area between the cathode plates (7);
- a power supply with connection for anode and cathode, **characterized in that** the electrostatic precipitator comprises at least one plate (14) with a number of holes (16) for passage of flue gas, wherein said at least one plate (14) is arranged in a position between the cathode plates (7) and comprises slots for lead-in of the cathode plates (7), such that the flow of flue gas during passage through the holes is regulated and distributed evenly between the cathode plates.

2. Electrostatic precipitator according to claim 1, **characterized in that**, the plate (14) is arranged in the cabinet (2) in a vertical direction compared to the flow of the flue gas from inlet (3) to outlet (4) through the Electrostatic precipitator.

3. Electrostatic precipitator according to one of the claims 1 or 2 , **characterized in that**, the size and position of the holes (16) are structured with a view to an even distribution of the flue gas between the cathode plates (7).

4. Electrostatic precipitator according to one of the preceding claims, **characterized in that**, the electrostatic precipitator further comprises a dividing plate (17) arranged in connection with the plate (14) for regulating the flow of flue gas.

5. Electrostatic precipitator according to claim 4, **characterized in that**, the dividing plate (17) is mounted over the opening(s) (16) in the plate (14) for regulating flue gas.

6. Electrostatic precipitator according to one of the preceding claims, **characterized in that**, the device consisting of the plate (14, 17) for regulating flow of flue gas is retained relative to the cabinet (2), but is in movable contact with at least one cathode plate (7) arranged on the rotatable shaft (8), and is adapted to function as a scraper (20) during contact with the cathode plate (7).

7. Electrostatic precipitator according to one of the claims 4 to 6,

characterized in that, the dividing plate (17) is equipped with a folded down edge (19), where the edge functions as a scraper (20).

8. Electrostatic precipitator according to claim 7, **characterized in that**, the folded down edge (19) measures between 10 and 100 mm with a preferred fold of 40 mm.

9. Electrostatic precipitator according to one of the claims 4 to 8, **characterized in that**, the dividing plate (17) forming a scraper is made from a flexible material having a thickness between 0,5 and 2,0 mm.

10. Electrostatic precipitator according to one of the claims 4 to 9, **characterized in that**, the dividing plate (17) forming a scraper is made from a flexible material with a thickness of 0,7 mm.

11. Electrostatic precipitator according to one of the claims 4 to 10, **characterized in that**, the dividing plate (17) forming a scraper contains fine-grained corrosion-resistant steel.

12. Electrostatic precipitator according to one of the claims 4 to 11, **characterized in that**, the dividing plate (17) forming a scraper is arranged resiliently suspended in contact with the cathode plate with a force between 2 and 10 N/cm, preferred value 5 N/cm.

13. Electrostatic precipitator according to one of the claims 4 to 12, **characterized in that**, the dividing plate (17) forming a scraper is arranged at the side of the cabinet (2) which faces towards the inlet (3) .

14. Electrostatic precipitator according to one of the claims 4 to 15, **characterized in that**, the dividing plate (17) forming a scraper is arranged in contact with the lower half-circle of the cathode plate (7) .

Patentansprüche

1. Elektrostatischer Abscheider, umfassend:

- ein Gehäuse (2) mit:
- einem Einlass (3) für das Einströmen von Rauchgas;
- einem Auslass (4) für das Ausströmen von gereinigtem Rauchgas;
- einer Halterung, die zwischen Einlass und Auslass angeordnet ist, um eine drehbare Welle (8) zu tragen, wobei auf der Welle eine Anzahl paralleler elektronisch leitfähiger Platten angeordnet ist, die so angepasst sind, dass sie als Kathoden (7) fungieren;
- einem Motor (6) zum Drehen der drehbaren Welle (8);
- einer Anordnung (11) zum Halten einer Anzahl von leitfähigen Fäden (10), die als Anoden fungieren, und zum Anordnen dieser Fäden derart, dass sie durch den Bereich zwischen den Kathodenplatten (7) geführt werden;
- einer Stromversorgung mit Anschluss zu Anode und Kathode, wobei die Vorrichtung **dadurch gekennzeichnet ist, dass** der elektrostatische Abscheider mindestens eine Platte (14) mit einer Anzahl von Löchern (16) zum Durchtritt von Rauchgas umfasst, wobei die mindestens eine Platte (14) in einer Position zwischen den Kathodenplatten (7) angeordnet ist und Schlitze zum Einführen der Kathodenplatten (7) umfasst, so dass der Rauchgasstrom während des Durchgangs durch die Löcher reguliert und gleichmäßig zwischen den Kathodenplatten verteilt wird.

2. Elektrostatischer Abscheider nach Anspruch 1, **dadurch gekennzeichnet, dass** die Platte (14) im Gehäuse (2) in Bezug auf den Rauchgasstrom vom Einlass (3) zum Auslass (4) durch den elektrostatischen Abscheider vertikal angeordnet ist.

3. Elektrostatischer Abscheider nach einem der Ansprüche 1 oder 2, **dadurch gekennzeichnet, dass** die Größe und Position der Löcher (16) im Hinblick auf eine gleichmäßige Verteilung des Rauchgases zwischen den Kathodenplatten (7) strukturiert sind.

4. Elektrostatischer Abscheider nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** der elektrostatische Abscheider ferner eine Trennplatte (17) umfasst, die in Verbindung mit der Platte (14) zum Regulieren des Rauchgasstroms angeordnet ist.

5. Elektrostatischer Abscheider nach Anspruch 4, **dadurch gekennzeichnet, dass** die Trennplatte (17) über der/den Öffnung(en) (16) in der Platte (14) zum Regulieren von Rauchgas montiert ist.

6. Elektrostatischer Abscheider nach einem der vorstehenden Ansprüche,
dadurch gekennzeichnet, dass
die Vorrichtung, die aus der Platte (14, 17) zum Regulieren des Rauchgasstroms besteht, relativ zu dem Gehäuse (2) gehalten wird, jedoch in einem beweglichen Kontakt mit mindestens einer Kathodenplatte (7) steht, die auf der drehbaren Welle (8) angeordnet und dazu ausgelegt ist, während des Kontakts mit der Kathodenplatte (7) als Abstreifer (20) zu fungieren.

7. Elektrostatischer Abscheider nach einem der Ansprüche 4 bis 6,
dadurch gekennzeichnet, dass
die Trennplatte (17) mit einer abgeklappten Kante (19) ausgestattet ist, wobei die Kante als Abstreifer (20) fungiert.

8. Elektrostatischer Abscheider nach Anspruch 7, **dadurch gekennzeichnet, dass**
die abgeklappte Kante (19) zwischen 10 und 100 mm mit einer bevorzugten Faltung von 40 mm misst.

9. Elektrostatischer Abscheider nach einem der Ansprüche 4 bis 8,
dadurch gekennzeichnet, dass
die Trennplatte (17), die einen Abstreifer bildet, aus einem flexiblen Material hergestellt ist, das eine Dicke zwischen 0,5 und 2,0 mm aufweist.

10. Elektrostatischer Abscheider nach einem der Ansprüche 4 bis 9,
dadurch gekennzeichnet, dass
die Trennplatte (17), die einen Abstreifer bildet, aus einem flexiblen Material mit einer Dicke von 0,7 mm hergestellt ist.

11. Elektrostatischer Abscheider nach einem der Ansprüche 4 bis 10,
dadurch gekennzeichnet, dass
die Trennplatte (17), die einen Abstreifer bildet, feinkörnigen, korrosionsbeständigen Stahl enthält.

12. Elektrostatischer Abscheider nach einem der Ansprüche 4 bis 11,
dadurch gekennzeichnet, dass
die Trennplatte (17), die einen Abstreifer bildet, in Kontakt mit der Kathodenplatte mit einer Kraft zwischen 2 und 10 N/cm, wobei der bevorzugte Wert 5 N/cm ist, elastisch suspendiert angeordnet ist.

13. Elektrostatischer Abscheider nach einem der Ansprüche 4 bis 12,
dadurch gekennzeichnet, dass
die Trennplatte (17), die einen Abstreifer bildet, an der Seite des Gehäuses (2) angeordnet ist, die dem Einlass (3) zugewandt ist.

14. Elektrostatischer Abscheider nach einem der Ansprüche 4 bis 15,
dadurch gekennzeichnet, dass
die Trennplatte (17), die einen Abstreifer bildet, in Kontakt mit dem unteren Halbkreis der Kathodenplatte (7) angeordnet ist.

Revendications

1. Précipitateur électrostatique comprenant :

- une enceinte (2) avec :
- une entrée (3) pour l’admission de gaz de combustion ;
- une sortie (4) pour l’écoulement de gaz de combustion purifié ;
- un support disposé entre l’entrée et la sortie adapté pour porter un arbre rotatif (8), sur ledit arbre est disposé un nombre de plaques électroconductrices parallèles qui sont adaptées pour fonctionner en tant que cathodes (7) ;
- un moteur (6) pour faire tourner l’arbre rotatif (8) ;
- un agencement (11) pour retenir un certain nombre de fils conducteurs (10), qui fonctionnent en tant qu’anodes et pour agencer ces fils de telle sorte qu’ils sont conduits à travers la zone entre les plaques de cathode (7) ;
- une alimentation électrique avec une connexion pour l’anode et la cathode, **caractérisé en ce que** le précipitateur électrostatique comprend au moins une plaque (14) avec un certain nombre de trous (16) pour le passage de gaz de combustion, ladite au moins une plaque (14) étant disposée dans une position entre les plaques de cathode (7) et comprenant des fentes pour l’entrée des plaques de cathode (7), de telle sorte que l’écoulement de gaz de combustion pendant le passage à travers les trous est régulé et distribué uniformément entre les plaques de cathode.

2. Précipitateur électrostatique selon la revendication 1, **caractérisé en ce que,**
la plaque (14) est disposée dans l’enceinte (2) dans une direction verticale par rapport à l’écoulement du gaz de combustion provenant de l’entrée (3) vers la sortie (4) à travers le précipitateur électrostatique.

3. Précipitateur électrostatique selon l’une des revendications 1 ou 2,
caractérisé en ce que,
la taille et la position des trous (16) sont structurées en vue d’une répartition uniforme des gaz de combustion entre les plaques de cathode (7).

4. Précipitateur électrostatique selon l’une des reven-

dications précédentes,
caractérisé en ce que,
le précipitateur électrostatique comprend en outre une plaque de séparation (17) agencée en raccord avec la plaque (14) pour réguler l'écoulement de gaz de combustion.

5. Précipitateur électrostatique selon la revendication 4, **caractérisé en ce que,**
la plaque de séparation (17) est montée sur la ou les ouvertures (16) dans la plaque (14) pour réguler le gaz de combustion.

6. Précipitateur électrostatique selon l'une des revendications précédentes,
caractérisé en ce que,
le dispositif constitué de la plaque (14, 17) pour réguler l'écoulement de gaz de combustion est retenu par rapport à l'enceinte (2), mais est en contact mobile avec au moins une plaque de cathode (7) agencée sur l'arbre rotatif (8), et est adapté pour fonctionner en tant que racleur (20) pendant le contact avec la plaque de cathode (7).

7. Précipitateur électrostatique selon l'une des revendications 4 à 6,
caractérisé en ce que,
la plaque de séparation (17) est équipée d'un bord replié (19), le bord fonctionnant comme un racleur (20).

8. Précipitateur électrostatique selon la revendication 7, **caractérisé en ce que,**
le bord replié (19) mesure entre 10 et 100 mm avec un pli préféré de 40 mm.

9. Précipitateur électrostatique selon l'une des revendications 4 à 8,
caractérisé en ce que,
la plaque de séparation (17) formant un racleur est réalisée à partir d'un matériau souple ayant une épaisseur comprise entre 0,5 et 2,0 mm.

10. Précipitateur électrostatique selon l'une des revendications 4 à 9,
caractérisé en ce que,
la plaque de séparation (17) formant un racleur est réalisée à partir d'un matériau souple ayant une épaisseur de 0,7 mm.

11. Précipitateur électrostatique selon l'une des revendications 4 à 10,
caractérisé en ce que,
la plaque de séparation (17) formant un racleur contient de l'acier résistant à la corrosion à grains fins.

12. Précipitateur électrostatique selon l'une des revendications 4 à 11,
caractérisé en ce que,
la plaque de séparation (17) formant un racleur est agencée en suspension élastique au contact de la plaque de cathode avec une force comprise entre 2 et 10 N/cm, avec une valeur préférée de 5 N/cm.

13. Précipitateur électrostatique selon l'une des revendications 4 à 12,
caractérisé en ce que,
la plaque de séparation (17) formant un racleur est disposée du côté de l'enceinte (2) qui est tourné vers l'entrée (3).

14. Précipitateur électrostatique selon l'une des revendications 4 à 15,
caractérisé en ce que,
la plaque de séparation (17) formant un racleur est disposée en contact avec le demi-cercle inférieur de la plaque de cathode (7).

Fig 1.

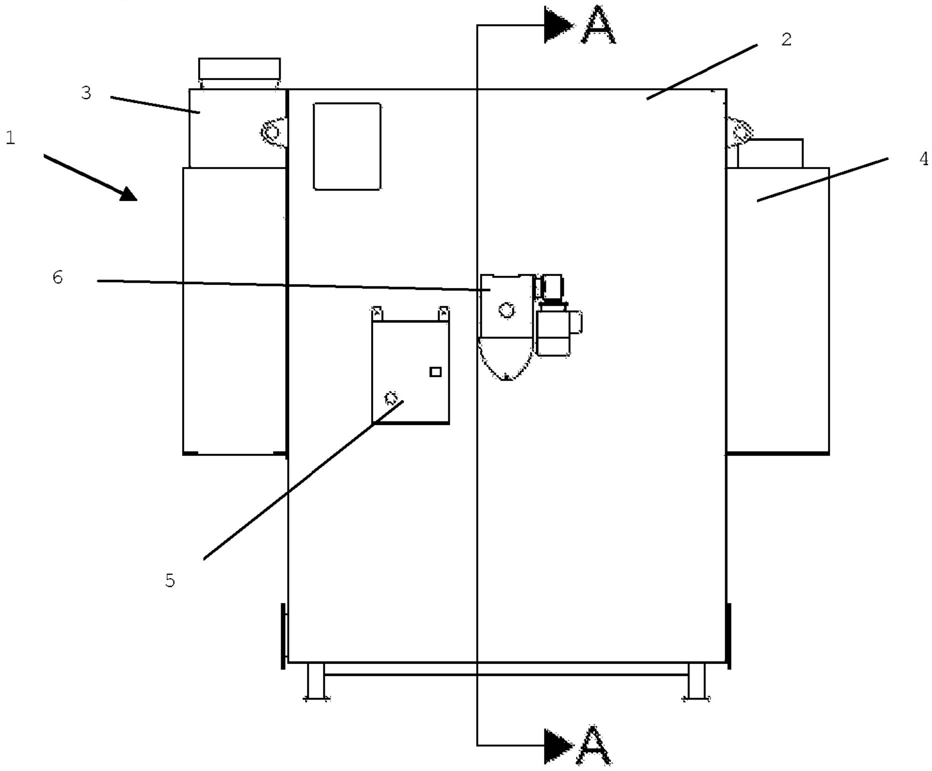
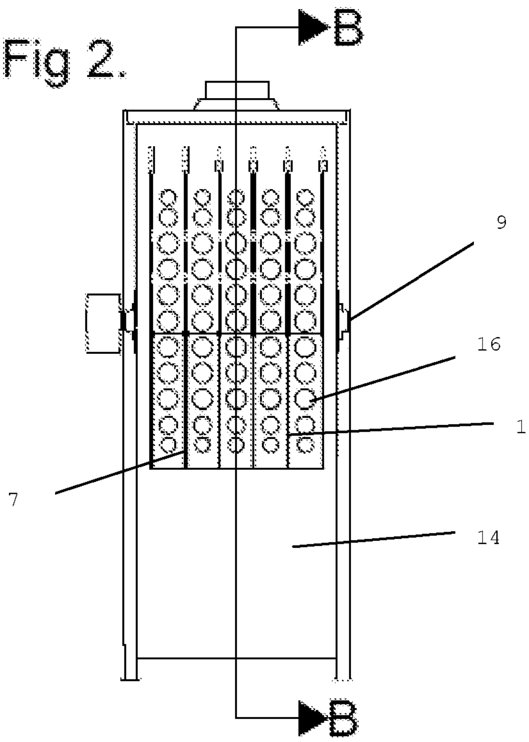


Fig 2.



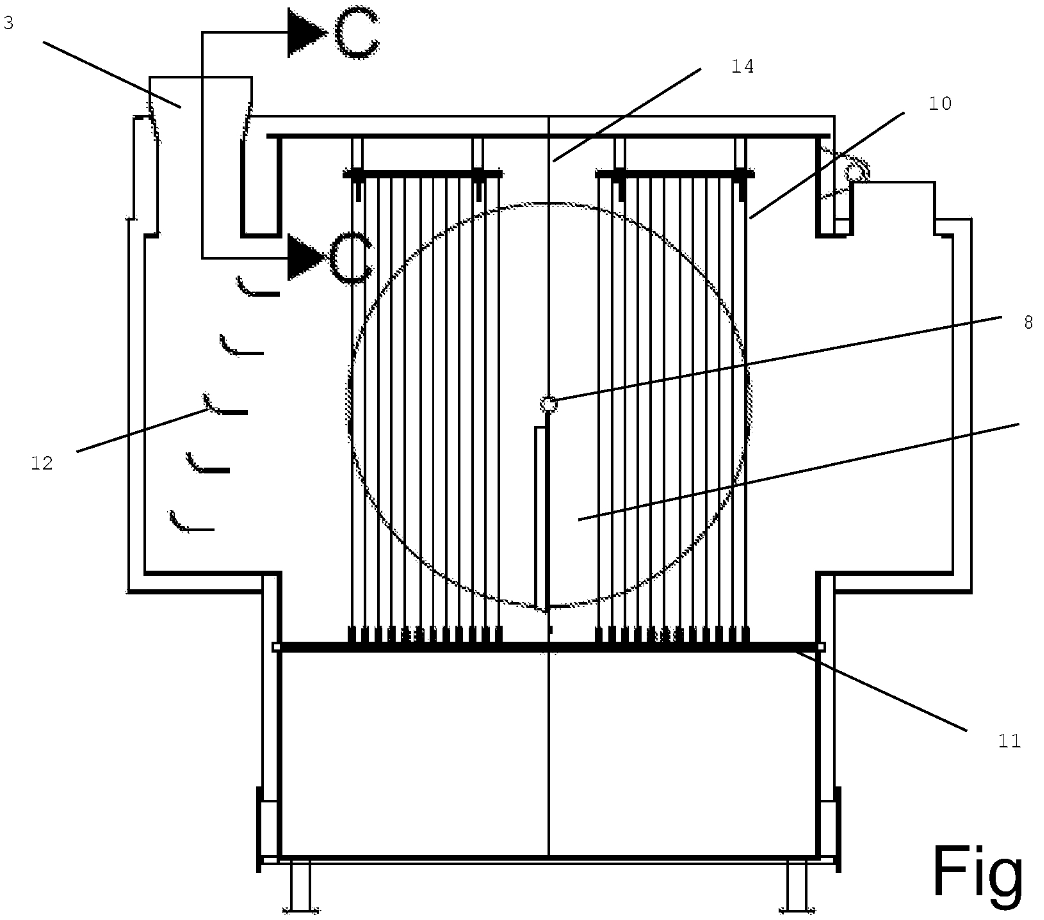


Fig 3.

Fig 4.

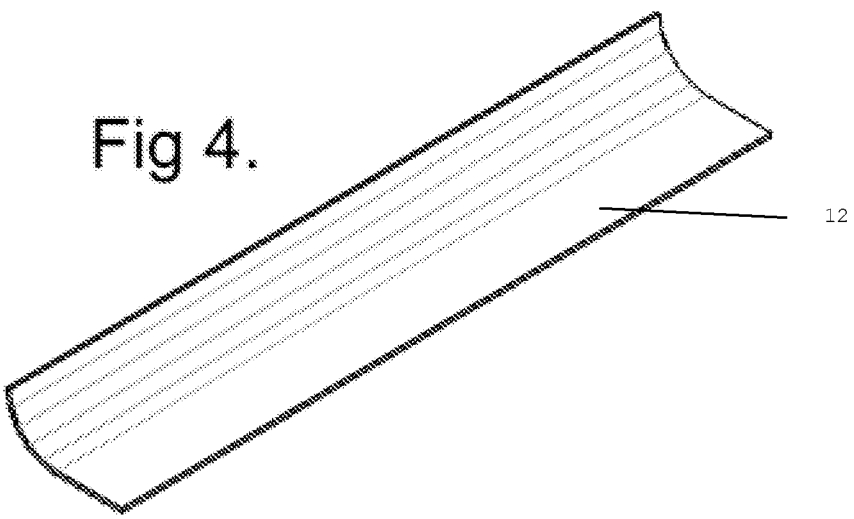


Fig 5.

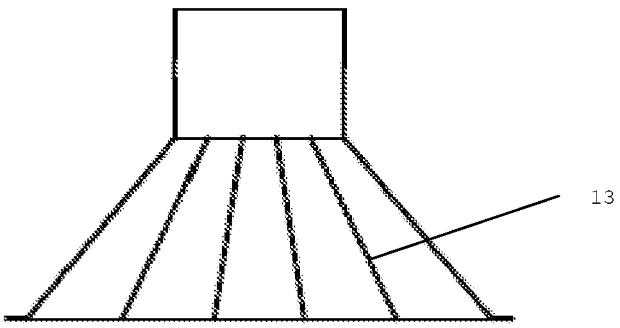


Fig 6.

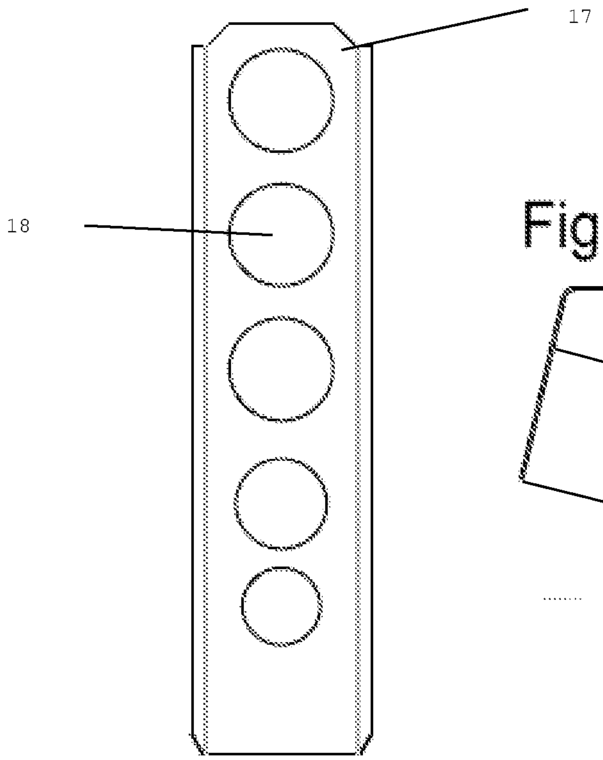


Fig 7.

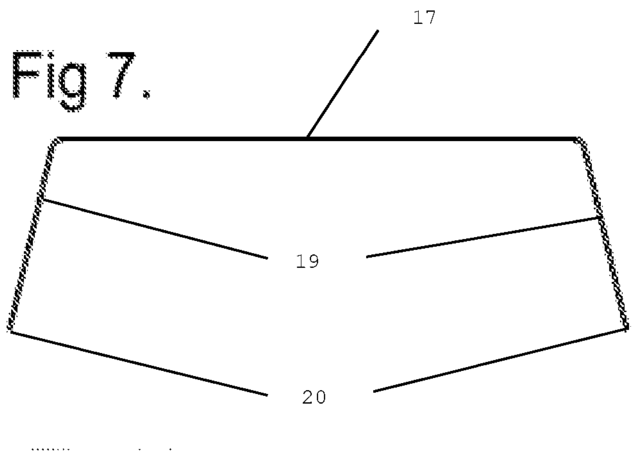


Fig 8.

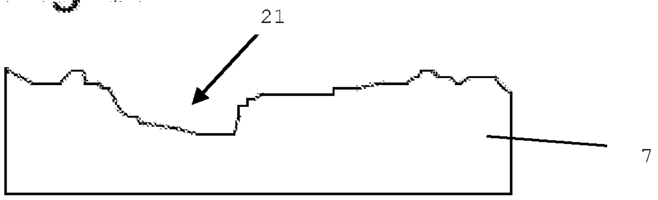


Fig 9.

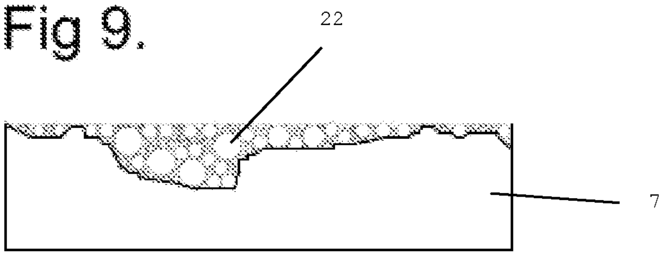


Fig 10.

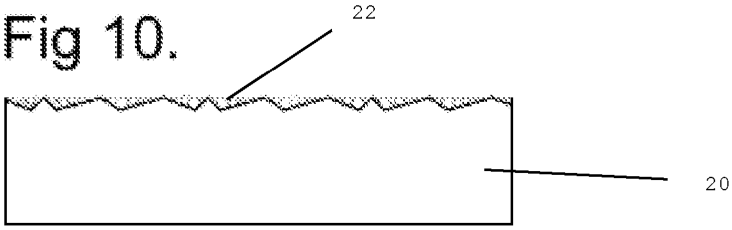


Fig 11.